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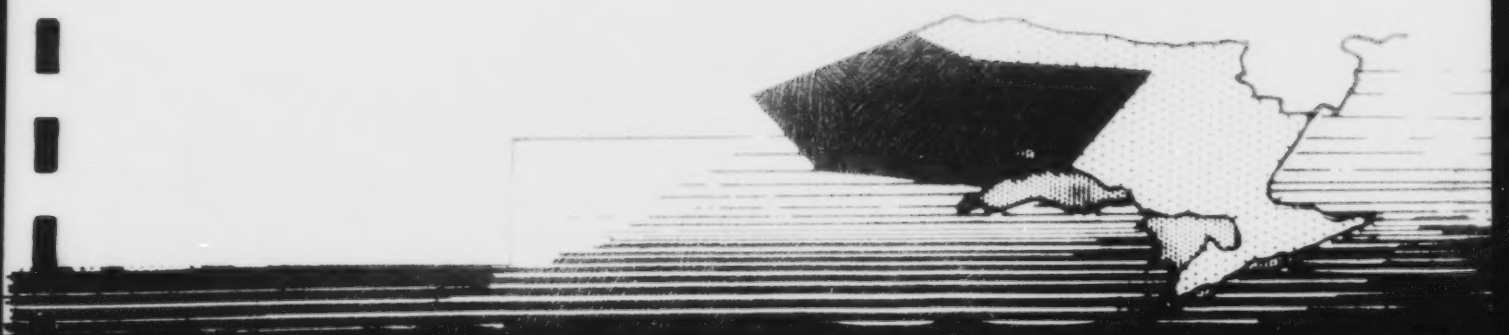

Ontario Ministry of Natural Resources

NORTHWESTERN ONTARIO FOREST TECHNOLOGY DEVELOPMENT UNIT

TOOLS FOR
SITE SPECIFIC SILVICULTURE
IN NORTHWESTERN ONTARIO

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Need For Silvicultural Planning

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Good morning ladies and gentlemen. I would like to first of all thank Al and the Northwestern Ontario Forest Technology Development Unit for giving me the opportunity to attend this session, and thank them as well for giving forestry staff within the industry and the Ministry of Natural Resources (MNR) an opportunity to get together to specifically discuss silviculture.

Industry, government, and educational institutions across this province are all feeling what many consider to be the adverse effects of living in a time of constraint. The dollars, manpower, and stock availability required to carry out our regular forestry business procedures have been stretched to their limit. Emerging from our current constraint situation however, have been two different lines of thought.

On one hand, there are those who are becoming frustrated as they lose their ability to manage forestry in their usual manner. They have reached a point where they can no longer fine-tune programs or restructure their priorities to accommodate traditional silvicultural programs. Feeling strong indignation towards decisions made beyond their control to cut funding and/or stock allocations, there are echoing cries across the province that any further cutbacks will place critical parts of the forestry program, including silviculture, in jeopardy. The "doing more with less" days are over! Ontario, by the way, is not unique in these feelings. I heard the same comments in a discussion with foresters from Michigan two weeks ago.

On the other hand, there are managers who are also watching their silviculture flexibility diminish, but are asking themselves an important question, "Is traditional silviculture something I really want?"

The definition of tradition, according to Oxford, is: The opinion or belief or custom handed down by ancestors to posterity either orally or by practice.

In many parts of Ontario there is often very little biological support for the silvicultural opinions, handed down from manager to manager, which have been in practice for years. I am certain, for example, that managers from both the MNR and the industry will go to the cutovers this summer to assess their sites for planting potential with the optimum target spacing of 1.8 m deeply engraved in their minds. The closer that they come to planting 3,000 trees/ha on their sites, the better it would appear that these managers are doing their jobs. I am also just as certain that there will be an inspection of that site by a supervisor or auditor, formal or otherwise, who will look at this site, bless the prescription that has been made, and it will be noted somewhere that all is well.

Following tradition is not to say that we've stagnated in silviculture by any means. On the contrary, technological advances in silviculture over the past 10 years have been on the uphill side of an exponential curve. What this has done is provide the manager with many more options towards obtaining the usual goals; to carry out, if you wish, the old way of doing business more efficiently. For example, instead of having only barrels and chains to meet the 3,000 trees/ha objective, the same manager has the choice of selecting methods such as crushing and burning, trenching, or spraying. He is also able to stick those 3,000 trees in the ground a lot faster now, using tree spades or hoedads instead of the old planting shovel. These will all do as good a job, if not better, as the traditional methods, and will usually result in cost savings. Unfortunately, these savings will probably go to regenerate another area using the same thought processes.

There may, however, be a silver lining to this cloud of recent constraints hovering over our heads. Perhaps it's time for us to consider non-traditional ways of doing business and start planning our silvicultural strategies by asking ourselves some basic questions like:

1) What type of product should be established on the site to meet the demands of the mill in 50-70 years?

2) Are the sawlogs that were taken from the site last year going to be required at the time of the next cut?

3) Should, or could, I be adjusting the spacing of my plantation to best suit this new crop and perhaps count on some (natural?) volunteers to help me out?

4) Will it be economical to harvest the stand at its proposed distance from the mill at the time of its rotation?

5) Should I be regenerating this site at all?

Crop planning is a term that we should all become familiar with. We had the reins put to us a couple of years ago because, at the time, it looked like our program was taking off on a tangent; running out of control. There didn't appear to be anything stopping the number of trees being produced or the money allocated to plant them. Those days are gone for sure!

Regardless of whether our provincial economic situation changes, or whether the Canada Ontario Forest Resource Development Agreement (COFRDA) or some other new source of funding comes to our rescue financially, we are going to have to justify what we're doing in silviculture. We have to impress upon the public that we know what we're doing, and we have to convince those who are calling the shots from a politically driven point of view to fund our programs.

Such planning is going to have to take place in conjunction with the Timber Management Plans (TMPs) and the MNR and company staff. Before a stand is cut, we are going to have to start looking at the options available to us, relative to a silviculture strategy, that will produce the best product required for the

future. We will have to become familiar with generic prescriptions such as Forest Ecosystem Classifications (FEC), or prime site management, or new developments, some of which you will hear about at this seminar, and then apply local knowledge to the formulae at a management level.

There's no reason to believe, in a world where we are all tugging on the same dollar, that we'll win this tugging match; not until we prove that we're making the right decisions and have solid information to back those decisions.

This leads us to another point. Part of good planning is keeping track of what we do so that we can learn from our mistakes and flaunt the things that have worked well. It will be critical then to have in place a mandatory, universal assessment system. One of the criticisms of our past is the number of great ideas that were implemented but never documented. We've spent millions of dollars, in the past decade, planting trees and seeding areas, but we are unable to demonstrate the fact that we know for sure that our regeneration efforts are successful and that our prescriptions are correct. The more information that we have to support the things we are doing, the better the position we will be in to convince the bank that we deserve a lion's share of the money pot.

This is not going to be a cakewalk folks. Many foresters with the MNR and industry are target driven. We have to make an effort to get away from that line of thought. At times, we are going to find it difficult biting the bullet and walking away from sites that we would normally spend thousands of dollars trying to regenerate. We may have to decide that the stand shouldn't be cut in the first place. The new forest production policy being prepared is going to have to address these issues as well.

We also have to contend with a public, and even some people within our own ministry, who are of the impression that we should still be planting two trees for every one cut, on all harvested sites. There will be some philosophical questions relating to why we should be allowed to cut a stand at all if we have no intentions of regenerating it.

The technology development units (TDUs) across this province have great potential to produce some of the groundwork for generic or site-specific silviculture. This could be used as the foundation on which to build a solid prescription at the management unit level. There's a lot of enthusiasm and, from what I've seen at their recent coordinators' meeting, some strong leadership within these TDUs. Whether you work for industry or with the MNR in a district, region or main office, I ask you to tap into this potential and become involved with developing some of the programs that will shape the future of silviculture. As well, I urge the TDUs to continue drawing upon the talent and experience in the field from within the MNR, the industry and universities, and also within the various sections of the Forest Resources Group.

Hopefully over the next two days, having listened to about 20 people make presentations (some of whom have devoted their lives to forestry), more of you will go home asking yourselves the question, "Is tradition what I want?"

Certainly you will hear some things that you may not agree with. Al and I have already had occasion to raise each others' blood pressure from time to time, about silviculture issues. But one thing that I agree with, most of the time, are the concepts being developed. In this light, I'm asking all of you to keep an open mind during this session and, if nothing else, listen to the concepts. Working as a team, I strongly feel that this province will have no problem in securing the forest requirements of the future through effective planning today.

Site Quality Evaluation for Forest Land in North Central Ontario

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ABSTRACT

Major results of site quality research at Lakehead University are described including: (a) polymorphic site index curves for jack pine (Pinus banksiana Lamb.), black spruce (Picea mariana (Mill.) B.S.P.), and trembling aspen (Populus tremuloides Michx.); (b) soil-site relations for jack pine (; and (c) site index curves and growth intercepts for planted white spruce (Picea glauca (Moench) Voss) and red pine (Pinus resinosa Ait.). Relations between site quality evaluation, yield prediction, and forest landscape classification are discussed.

INTRODUCTION

Forest site quality expresses the capability of forest land for growing trees, thus site quality estimation corresponds to land capability estimation for growing agricultural crops (Carmean 1975). Productive (good site quality) forest lands close to mills (prime forest sites) should be managed most intensively, and less productive (poor site quality) forest lands far from mills should be managed less intensively. This same emphasis is followed in agriculture where intensive agricultural practices are normally concentrated on the most productive croplands. Advantages of concentrating intensive forest management on productive forest lands are listed in Table 1.

Table 1. Advantages of concentrating intensive management on productive forest lands.

1.	Productive sites produce a GREATER QUANTITY of yield.
2.	Productive sites produce a BETTER QUALITY of yield.
3.	Productive sites produce large trees sooner, thus SHORTER ROTATIONS are possible.
4.	Productive sites are MORE RESPONSIVE to intensive management practices such as site preparation, release and thinning.
5.	Productive sites are best for species valued for SAWLOG AND VENEER LOG production.

Ontario forest land varies greatly in stand composition, and also in soil, topography and site quality. However, our resources of funds and forestry manpower are limited, thus we must be selective and must concentrate our most intensive forest management on our most productive and accessible forest lands. Unfortunately we presently lack precise means for identifying these productive forest lands, i.e., for identifying site quality. Likewise we lack precise means for predicting the growth and yield that can be attained for each of the several alternative tree species that might be managed on these productive sites.

Many methods can be used for estimating forest site quality (Table 2), but all methods have the common goal of estimating forest land capability for tree growth. The method to use for estimating site quality depends upon forest stand conditions. Site quality can be directly estimated using forest trees if: (a) undisturbed, even-aged, fully stocked older stands are available; (b) free-growing, uninjured dominant and codominant trees are present; and (c) accurate site index curves or growth intercepts are available (Carmean 1975, Carmean et al. 1989).

Table 2. Many methods can be used for estimating forest site quality.

A.	DIRECT ESTIMATION OF SITE INDEX FROM FOREST TREES
	1. Site index curves - harmonized site index curves - polymorphic site index curves
	2. Growth intercepts
	3. Site index comparisons between species
B.	INDIRECT ESTIMATION OF SITE INDEX FROM SOIL, VEGETATION AND TOPOGRAPHY
	1. Soil-site evaluation
	2. Soil types
	3. Habitat, ecosystem, and physiographic types

Site quality cannot be directly estimated for cutover areas and for poorly stocked, very young, and uneven-aged stands. For such areas, indirect methods of site quality estimation can be used including: soil-site methods, soil types, and habitat types. But using these indirect methods requires research that accurately relates site quality to specific soil and vegetal features, or to units defined in soil and vegetal classification systems.

An integrated program of site quality research that includes each of the direct and indirect methods of site quality estimation (Table 2), is under way at Lakehead University. A brief review of this site quality research program was given at the 1985 COJFRC Symposium (Carmean 1986), and at a University of Guelph Workshop (Carmean 1988). My talk today will briefly describe the current status of our site quality studies for forest species in north central Ontario.

Polymorphic Site Index Curves

Directly estimating site index from forest trees is the most commonly used method for estimating site quality in North America (Carmean 1975, Carmean et al. 1989). This method requires total height and total age measurements from several dominant, or dominant and codominant trees. Measurements from each site tree are then related to a family of site index curves for an estimate of total tree height at a specified index age. For most eastern species a total age of 50 years is the commonly used index age; for longer-lived western species a total age of 100 years is often used as the index age. Age from breast height is sometimes used for species having slow and erratic height growth below breast height; younger index ages are sometimes used for short-lived species, species managed on short rotations, or for young plantations.

Accurate direct site index estimates depend upon: (a) availability of suitable stands and site trees that are dependable indicators of site quality; and (b) availability of site index curves that accurately portray tree height growth patterns for the area or soil and site conditions where site quality is estimated. Suitable site trees are free-growing, uninjured, dominant, and co-dominant trees. Such trees occur in older, even-aged, fully stocked stands not disturbed by past cutting, severe fires, or heavy grazing. Select the best dominant and codominant trees in the stand. Increment cores should be carefully studied to see if early rings are narrow and suppressed; this indicates that height growth probably also was suppressed - such trees should be rejected. Study the bole and look for forks or "dog legs"; these trees probably have suffered from top breakage or die back, and thus are not suitable as site trees.

Even when suitable stands and site trees are available, considerable error in site index estimation can occur when site index curves may not accurately express patterns of tree height growth; i.e., early or later height growth may be different from that expressed in existing site index curves. For many forest species, existing site index curves might be based on minimum data, on harmonizing methods using only total height and total age values, and on growth models that are not suitable for expressing variable (polymorphic) tree height growth patterns. Stem analysis (or internode measurements) is now the favoured method for data collection. Nonlinear regression models are suited for developing site index curves capable of expressing polymorphic tree height growth patterns (Carmean 1975, Carmean et al. 1989).

Few site index curves are available for forest species in northern Ontario, but the anamorphic site-class curves developed by Plonski (1974) are commonly used for various conifer and hardwood species. However, age, site quality, soil conditions, stand locations, and computation methods were not described for the Plonski site-class curves. Thus, we are not certain about their precision or the conditions where these site-class curves apply.

Site Index Curves for Jack Pine (Lenthall 1986, Carmean and Lenthall 1989)

Stem analyses data were taken from three to five dominant and codominant jack pine (Pinus banksiana Lamb.) growing in 141 site plots in north central Ontario (Figure 1). All plots were in natural, mature, fully stocked, even-aged, undisturbed stands. A wide range of jack pine site index was observed for plots located on four major glacial landforms (Table 3).

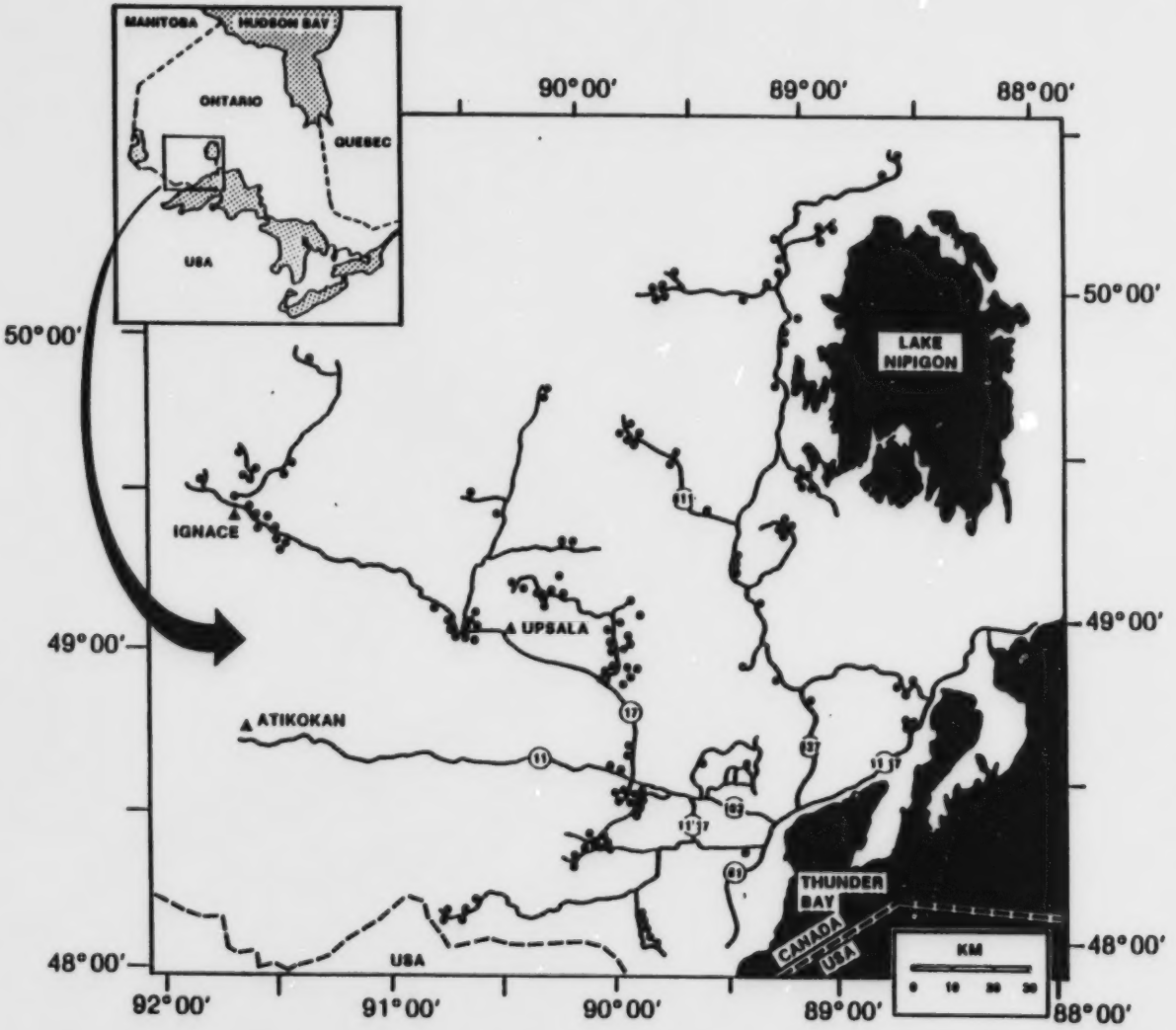

Figure 1. Locations for 141 jack pine site plots established in north central Ontario (Lenthall 1986, Carmean and Lenthall 1989).

Table 3. Site index of jack pine varies greatly for 141 plots located on four major landforms in north central Ontario (Lenthall 1986, Carmean and Lenthall 1989).

	Plots per site index class					
Landform	<11.5 m	11.5-14.4 m	14.5-17.4 m	17.5-20.4 m	>20.4 m	Totals
Shallow to bedrock*	9	8	10	2	0	29
Moraines	0	3	20	17	3	43
Glaciofluvial	0	5	15	30	1	51
Lacustrine	0	1	5	9	3	18
Totals	9	17	50	58	7	141

NOTE: Site index is total height (m) of dominant and codominant trees at 50 years breast height age.
* Shallow to bedrock morainal soils are <1.0 m to bedrock

These stem analyses data were used with a nonlinear regression model to compute polymorphic site index curves for jack pine, based on breast height age (Figure 2A).

Additional results from the Lenthall study show:

(a) Site index curves based on breast height age were more precise than curves based on total age;

(b) Average height growth patterns were similar for jack pine growing on four glacial landforms - shallow to bedrock, moraines, glaciofluvial, and lacustrine soils;

(c) Polymorphic height growth patterns were related to site index level, becoming more curvilinear as site index increased; and

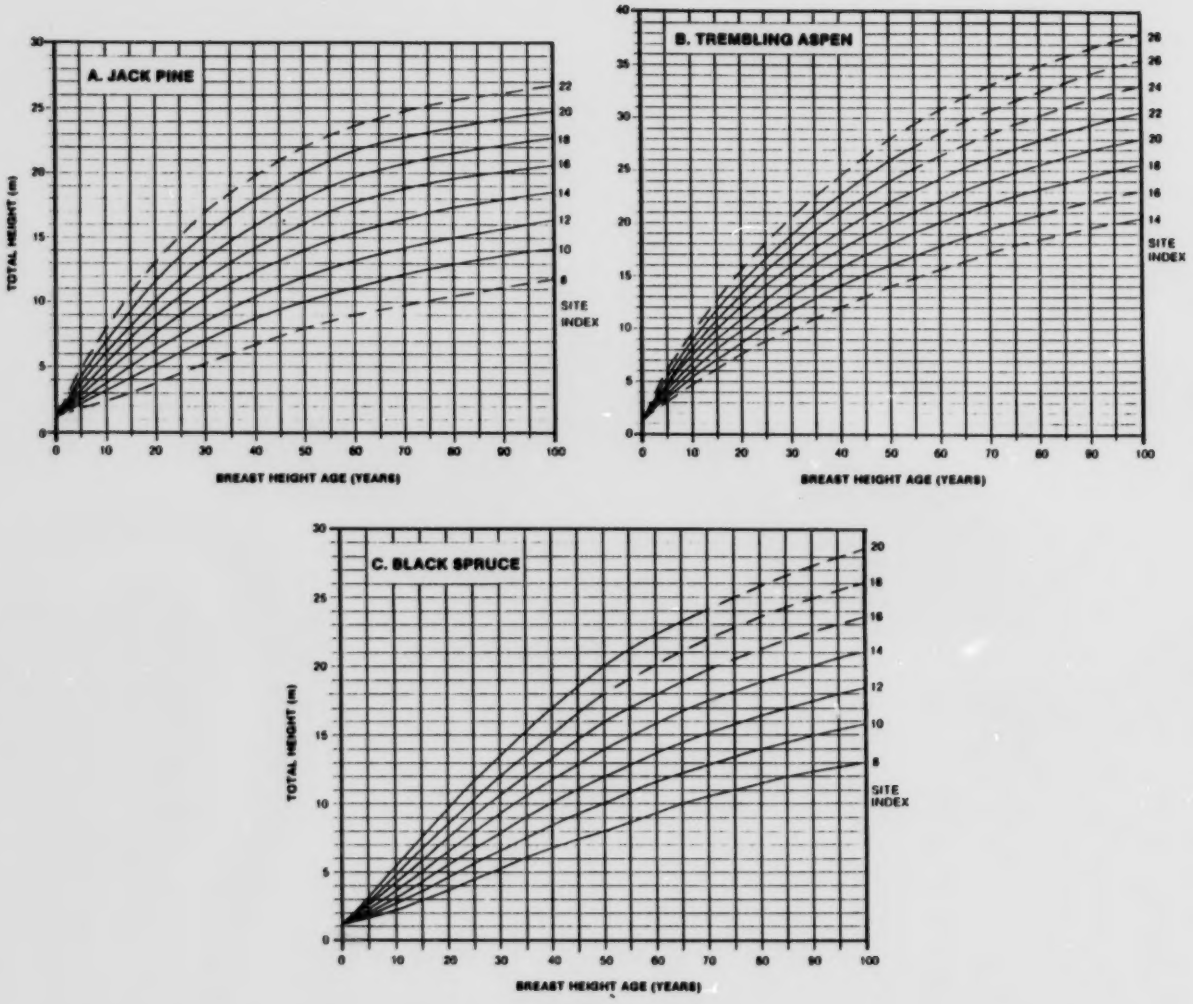

Figure 2. Site index curves for jack pine (Lenthall 1986, Carmean and Lenthall 1989), black spruce (Thrower 1986b), and trembling aspen (Deschamps 1989) in north central Ontario. For these three species site index is total height of dominant and codominant trees at 50 years breast height age.

(d) Height growth patterns were similar to Plonski's (1984) jack pine site class curves for ages less than 50 years, but after 50 years height growth for all sites was somewhat better than predicted by Plonski.

Site Index Curves for Black Spruce (Thrower 1986b)

Site plots established by Lenthall (1986) in the jack pine site index curve study frequently had a few free-growing dominant and codominant black spruce (Picea mariana (Mill.) B.S.P.) trees. So stem analyses data also were collected from two to five black spruce trees on 44 of Lenthall's site plots. Preliminary site index computations were made by Grant (1984), and further computations were made by Thrower (1986b). These computations were used to construct polymorphic site index curves for black spruce based on breast height age (Figure 2B).

Site Index Curves for Trembling Aspen (Deschamps 1989)

Stem analyses data were taken from dominant and codominant trembling aspen (Populus tremuloides Michx.) trees growing in 99 site plots. Some of these sectioned trees were occasional dominant and codominant aspen that were present on 19 jack pine site plots established by Lenthall (1986); dominant and codominant trees also were sectioned from 80 additional plots established in essentially pure aspen stands. Data from those aspen site plots were used to compute polymorphic site index curves for trembling aspen based on breast height age (Figure 2C).

Site studies for trembling aspen in north central Ontario are continuing (Augustyn 1989). Additional site plots will be located representing a wider range of soil and site quality conditions for aspen. These data will be used for defining aspen soil-site relations, leading to better recognition of productive forest lands where aspen can produce large yields of high value products. These analyses also will better define "off-site" aspen lands where aspen can produce only small yields of low grade fibre (Carmean 1985).

Soil-Site Relations for Jack Pine

Site quality cannot be directly estimated for forest lands that have been clearcut or partially cut, or where stands are uneven in age, are poorly stocked, or are very young. Such areas lack suitable trees for estimating site index. However, site quality can be estimated using the soil-site method of indirectly estimating site index. This method is based on research where site index is directly measured on a large number of plots representing the full range of site quality, soil and topography of a particular area or region. Site index directly measured on these plots is then correlated with the soil and topographic features observed on the plots. The resulting multiple regression equations can be used for developing site prediction tables for use in areas where stands and trees are not suitable for directly estimating site index.

Soil-site relations for jack pine in north central Ontario were studied by Schmidt (1986) and Schmidt and Carmean (1988) using most of the site plots established by Lenthall (1986). Site index values based on stem analyses were available for each of these plots, and detailed soil and topographic data were taken from 99 plots. These data were then used for computing soil-site multiple regressions for four major glacial landforms (Table 4).

These regression equations were used to construct trend graphs (Figure 3) for the four glacial landforms illustrating relations between site index for jack pine and the significant features listed in the regression equations (Table 4). These equation also were used to develop site index prediction tables (Table 5) for use by practicing foresters in estimating jack pine site index on lands where trees are not suitable for directly estimating site index. The precise values in these tables are for management situations where precise site index estimates may be needed, such as for small research areas. In contrast, less precise site index estimates may be sufficient for most forest management situations. Accordingly, a generalized version of Table 5 groups site index values into six 2-metre site classes (Table 6).

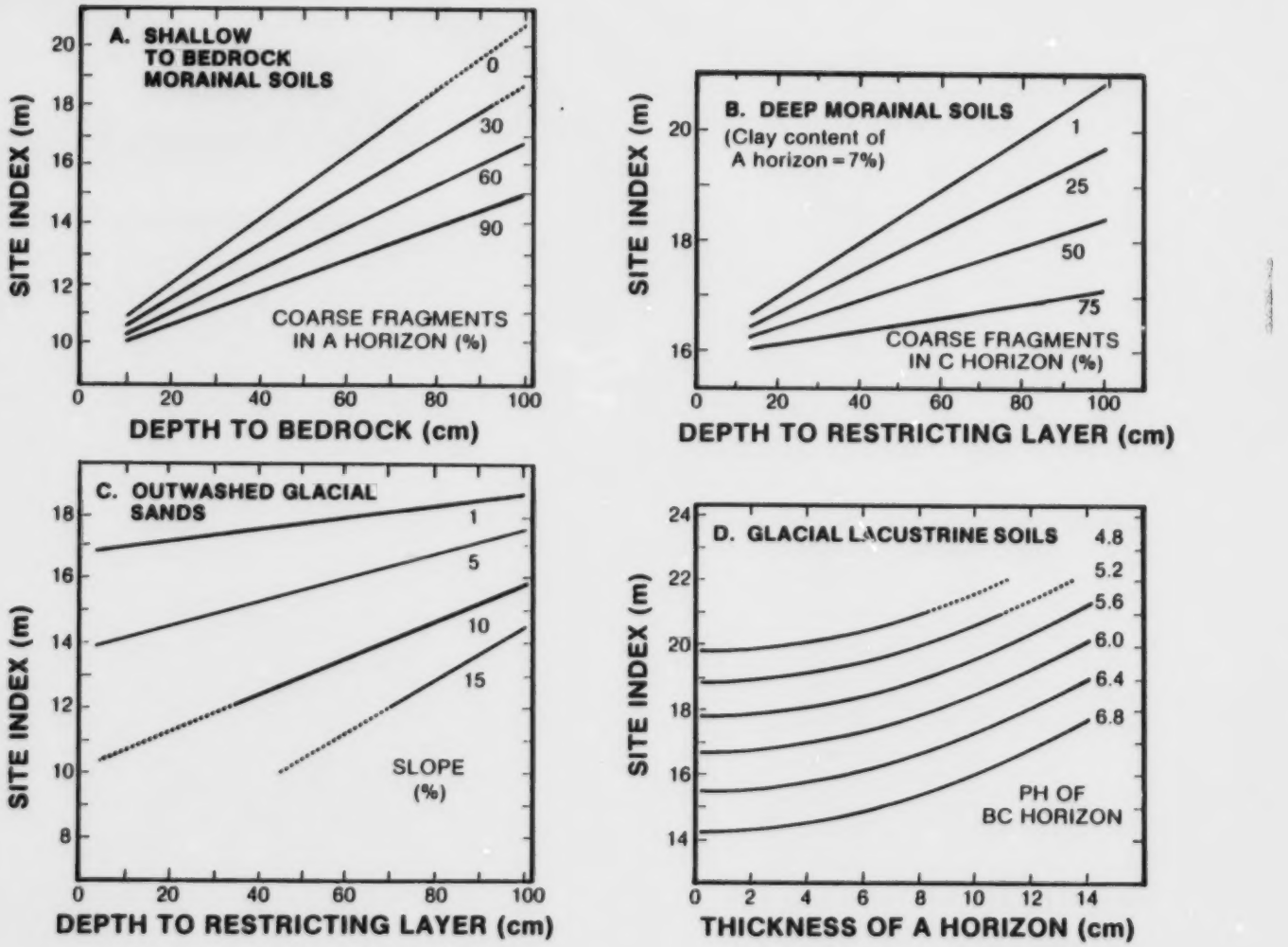

Figure 3. Trend graphs illustrating relationships between jack pine site index and features of soil and topography in north central Ontario (Schmidt 1986, Schmidt and Carmean 1988).

Table 4. Multiple regression equations expressing relations between jack pine site index and features of soil and topography for landforms in north central Ontario (Schmidt 1986, Schmidt and Carmean 1988).

Landform	No. of Plots	Equation	R2	SEE
Shallow to bedrock	20	SI= 9.42 + 0.11 DBR - 0.0006 (DBR x CoFrag A)	0.83	1.28
Moraines	30	SI= 18.54 + 0.00051 [DRL x (100 - CoFrag C)] - 0.38 ClA	0.65	1.26
Glaciofluvial	31	SI= 17.56 + .10 DRL - 0.73 Slope - 0.0044 [DRL x (20 - slope)]	0.65	1.26
Lacustrine	18	SI= 25.38 + 0.018 (ThA)^2 - 0.24 (pH BC)^2	0.75	1.07

WHERE:

SI	=	Site index is total height (m) of dominant and codominant trees at 50 years breast height age
DBR	=	Depth to bedrock (cm)
DRL	=	Depth to root restricting layer (cm)(i.e., coarse sandy subsoil, mottles, gley, water table, bedrock, carbonates or basal till)
ThA	=	Thickness of A horizon (%)
CoFrag A	=	Coarse fragments in A horizon (%)
CoFrag C	=	Coarse fragments in C horizon (%)
ClA	=	Clay content of A horizon (%)
pH BC	=	pH of BC horizon
Slope	=	Slope steepness (%)

Table 5. Site index prediction tables for jack pine on four glacial soil groups in north central Ontario (Schmidt 1986, Schmidt and Carmean 1988).

A. SHALLOW TO BEDROCK MORAINAL SOILS:

Depth to Bedrock	Coarse fragments in A horizon (%)			
	0-15	15-30	30-50	50-70
<15	10.2	10.1	10.1	10.0
15-30	11.8	11.6	11.4	11.1
30-50	13.6	13.3	12.9	12.4
50-70	15.8	15.2	14.6	13.9
70-100	18.4	17.6	16.7	15.7

B. DEEP MORAINAL SOILS:

Depth to root-restricting layer [a]	Coarse fragments in C horizon (%)								
	<40			40 - 70			>70		
	Clay in A hor (%)			Clay in A hor (%)			Clay in A hor (%)		
(cm)	2 - 4	5 - 7	8 - 10	2 - 4	5 - 7	8 - 10	2 - 4	5 - 7	8 - 10
<30	18.0	16.8	15.7	17.7	16.6	15.5	17.5	16.4	15.2
30 - 70	19.3	18.2	17.0	18.5	17.4	16.3	17.8	16.6	15.5
70 - 100	20.7	19.5	18.4	19.4	18.2	17.1	18.0	16.9	15.8

C. OUTWASHED GLACIAL SANDS:

Depth to root restricting layer [a] (cm)	Slope (%)			
	<3	3 - 6	6 - 9	>9
<30	16.7	14.8	12.8	10.8
30 - 60	17.3	15.7	14.1	12.5
60 - 90	17.9	16.7	15.5	14.3
90 - 120	18.4	17.6	16.8	16.0

D. GLACIAL LACUSTRINE SOILS:

Thickness of A horizon (cm)	pH of BC horizon			
	<5.3	5.3 - 5.9	5.9 - 6.5	>6.5
<4	19.3	17.9	16.2	14.5
4 - 8	19.9	18.5	16.8	15.1
8 - 12	21.1	19.7	18.0	16.2
12 - 16	22.8	21.4	19.7	18.0

NOTE: Site index is the total height (m) of dominant and codominant trees at 50 years breast height age.

[a] Depth to root restricting layer is depth to basal till, bedrock, coarse sand, mottles, gley, water table, or carbonates.

Table 6. Site index classes for jack pine on four glacial soil groups in north central Ontario (LeBlanc 1988).

A. SHALLOW TO BEDROCK MORAINAL SOILS:

Depth to Bedrock	Coarse fragments in A horizon (%) 0-15	15-30	30-50	50-70
<15	6			6
15-30	5			5
30-50	4			
50-70	2	3	4	
70-100				

B. DEEP MORAINAL SOILS:

Depth to root-restricting layer [a] (cm)	Coarse fragments in C horizon (%) <40			40 - 70			>70		
	Clay in A hor (%) 2 - 4	5 - 7	8 - 10	2 - 4	5 - 7	8 - 10	2 - 4	5 - 7	8 - 10
<30		3	4	3		4	3		4
30 - 70	2		3			3		3	
70 - 100	1	2		2			2		4

C. OUTWASHED GLACIAL SANDS:

Depth to root restricting layer [a] (cm)	slope (%) <3	3 - 6	6 - 9	>9
<30		4	5	6
30 - 60	3		4	5
60 - 90	2	3		
90 - 120				

D. GLACIAL LACUSTRINE SOILS:

Thickness of A horizon (cm)	pH of BC horizon <5.3	5.3 - 5.9	5.9 - 6.5	>6.5
<4	1	2	3	4
4 - 8	2	3		
8 - 12				
12 - 16				

SITE CLASS FOR JACK PINE	SITE INDEX RANGE FOR JACK PINE (m)
1	>20.0
2	18.0 - 19.9
3	16.0 - 17.9
4	14.0 - 15.9
5	12.0 - 13.9
6	<11.9

NOTE: Site index is the total height (m) of dominant and codominant trees at 50 years breast height age.

[a] Depth to root restricting layer is depth to basal till, bedrock, coarse sand, mottles, gley, water table, or carbonates.

An additional benefit of these soil-site analyses is that features found to be significantly related to site quality can be used for refining or defining landscape classification units described in the Ontario FEC (Forest Ecosystem Classification) Program (Sims et al. 1986), and in the Ontario Prime Site Program (Nicks 1985). For example, depth and coarse fragment content were found to be consistently related to jack pine site index, thus these features should be emphasized in forest land classification systems that have the goal of classifying productivity of land for tree growth.

The polymorphic site index curves and soil-site relations described above for jack pine are based only on site plots located in north central Ontario. Thus we presently cannot judge how applicable these results are to other regions of northern Ontario. Glacial geology, soil conditions, latitude, and climate in north central Ontario are generally similar to the conditions in other regions of northern Ontario. Even so, before applying our results to these other regions we should first-of-all make quantitative tests to determine how applicable our results are to these other regions. Presently the Ontario Ministry of Natural Resources is assisting us in collecting stem analysis and soil profile data from mature jack pine stands located in northwestern, northern and northeastern Ontario. These data will be independently analyzed and compared to results for north central Ontario. The final goal of these studies is to use data from all regions for developing site index curves and soil-site results for jack pine that are applicable throughout northern Ontario.

Growth Intercepts and Site Index Curves for Planted White Spruce and Red Pine (Thrower 1986a)

Thrower (1986a) developed site index curves and growth index intercepts for white spruce (Picea glauca (Moench) Voss) and red pine (Pinus resinosa Ait.) plantations in north central Ontario. These results are based on internode measurements and stem analyses from dominant trees in 46 white spruce and 25 red pine plots; all

plots were located in plantations 19 years and older since planting. Thrower found that both white spruce and red pine had slow and erratic height growth before reaching breast height. This early height growth was so erratic that only a weak relationship was found between site index and years to reach breast height. Most site index curves are based on total age, but Thrower's results show that considerable error will be involved if this erratic early growth below breast height is included in site index curve computations. Accordingly, computed site index curves for planted white spruce are based on a breast height age of 15 years, and computed site index curves for red pine are based on a breast height age of 20 years. (Figure 4) (Thrower and Carmean 1989, Carmean and Thrower 1989).

The growth intercept method of site quality estimation uses a period of early height growth rather than long-term (50 years) height growth as an index of site quality. This method was developed for conifers having distinct internodes marking annual height growth; usually the average length (or total length) of the first five internodes above breast height is used as an index of site quality. Height growth below breast height is usually slow and erratic, thus internode measurements are started above breast height where more consistent and more rapid internode lengths are closely related to later height growth and to site index (height at 50 years). The growth intercept method is particularly useful for plantations where trees are too young for using site index curves based upon dominant height at 50 years.

Thrower found that growth intercepts for both white spruce and red pine were more precise when internode measurements were started somewhat higher than the commonly used breast height level. For white spruce, growth intercepts should begin at the first internode above 2.0 m (Thrower 1986a, Thrower 1987, Thrower and Carmean 1989); for red pine, growth intercepts should begin at the first internode above 1.5 m (Thrower 1986a, Carmean and Thrower 1989).

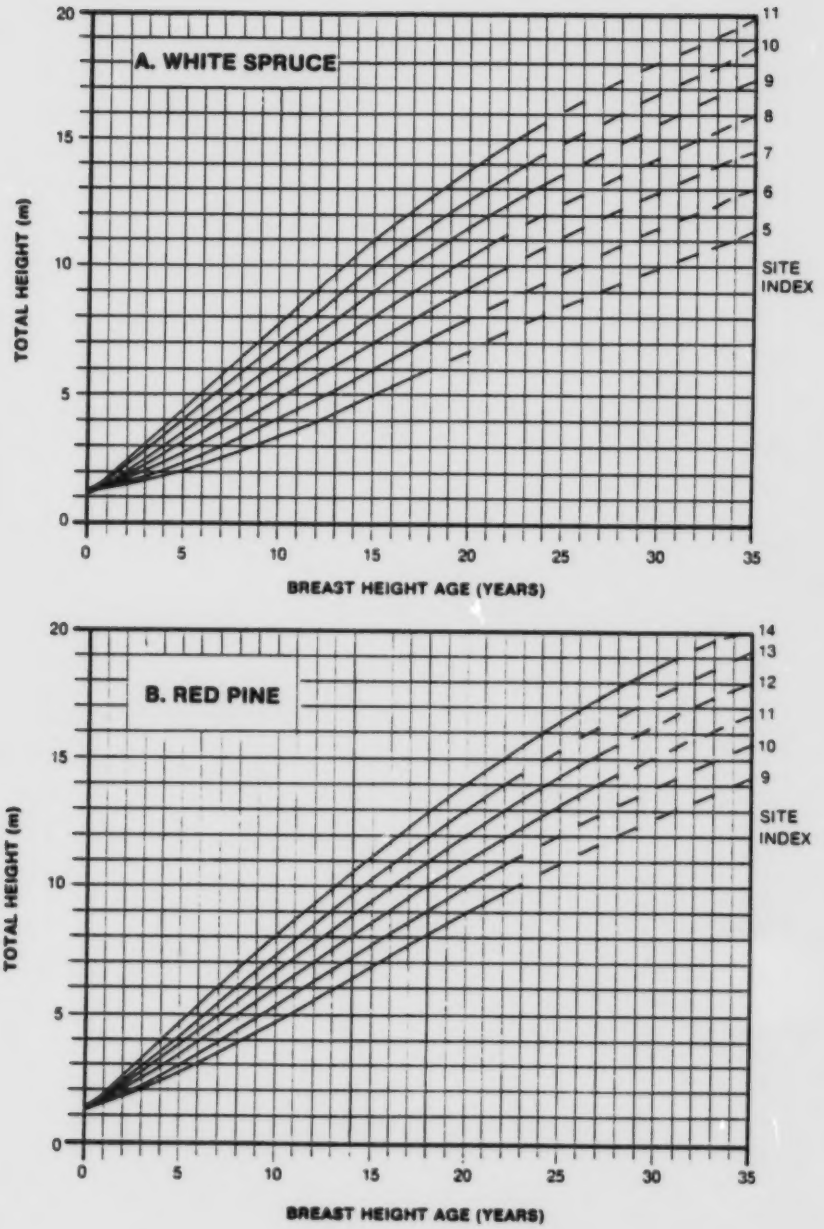

Figure 4. Site index curves for white spruce and red pine plantations in north central Ontario (Thrower 1986a, Thrower and Carmean 1989, Carmean and Thrower 1989). Site index for white spruce ($BHSI_{15}$) is total height of dominant trees at 15 years breast height age; site index for red pine ($BHSI_{20}$) is total height of dominant trees at 20 years breast height age.

For both species, growth intercepts (average length of the first three to five internodes) were closely related to site index (Figure 5). These growth intercept relationships are given in Table 7 for use in the field estimation of site index for planted white spruce and red pine.

Table 7. Site index estimates for planted white spruce and red pine in north central Ontario are related to growth intercept length (Thrower 1986a, Thrower and Carmean 1989, Carmean and Thrower 1989).

Growth Intercept length (m)	White spruce Site Index	Red Pine Site Index
0.25	5.5	8.8
0.30	6.4	9.3
0.35	7.3	9.8
0.40	8.1	10.4
0.45	8.7	11.1
0.50	9.3	11.9
0.55	9.8	12.7
0.60	10.1	13.7
0.65	10.4	14.6

NOTE: For white spruce, site index is total height of uninjured, free-growing dominant trees at 15 years breast height age; growth intercept is the average length of the first three to five internodes above 2.0 m measured on uninjured, free-growing dominant trees.

For red pine, site index is total height of uninjured, free-growing dominant trees at 20 years breast height age; growth intercept is the average length of the first three to five internodes above 1.5 m measured on uninjured, free-growing dominant trees.

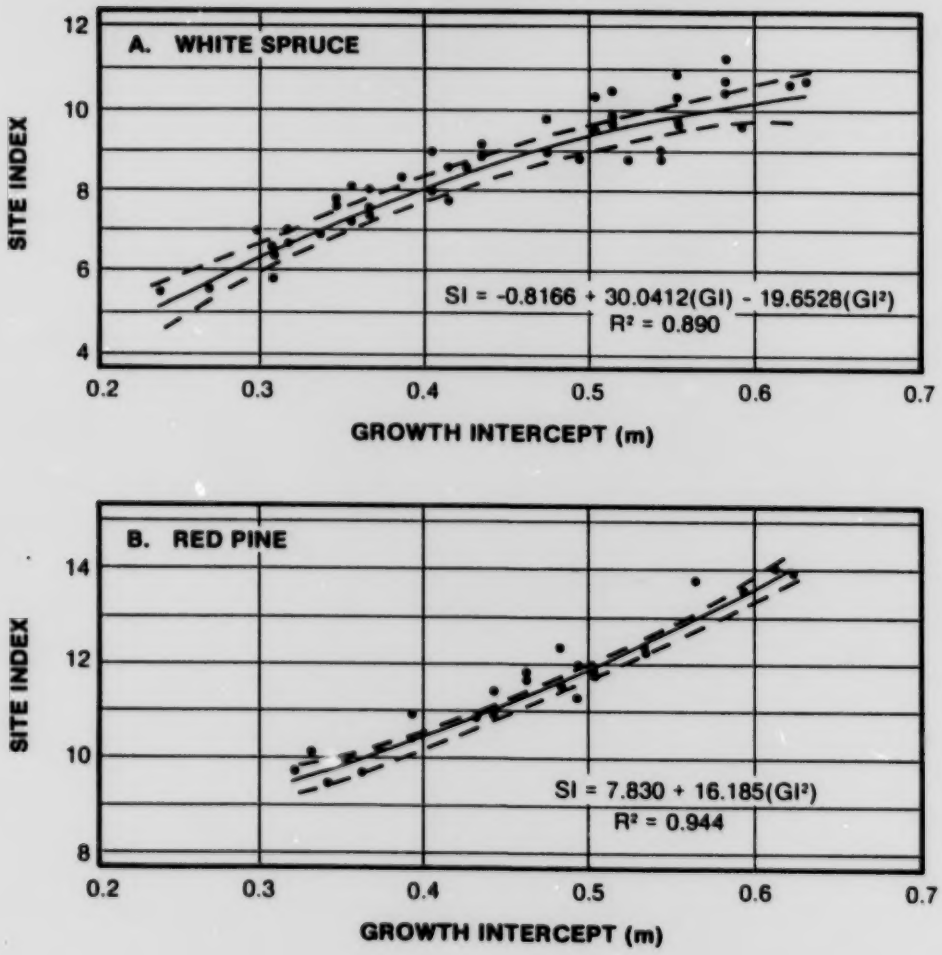

Figure 5. Site index for white spruce ($BHSI_{15}$) and red pine ($BHSI_{20}$) planted in north central Ontario is closely related to growth intercept length (Thrower 1986a, Thrower 1987, Thrower and Carmean 1989, Carmean and Thrower 1989). These illustrated close relations are for growth intercepts based on the average length of five internodes, but growth intercepts based on the average length of four and three internodes were almost as precise.

Application of Table 7 requires measuring growth intercepts from several well-formed, uninjured dominant trees. For each selected site, tree identify the starting point for internode measurements... 2.0 m for white spruce and 1.5 m for red pine. Then obtain the total length of the first three to five internodes above this starting point; growth intercept is the average internode length based on measurements from these three to five internodes.

Site studies for planted white spruce in north central Ontario are continuing. Additional plots in older white plantations were located and preliminary soil-site relations have been computed (La Valley 1989). These results will be useful in defining the most productive sites for planting white spruce.

DISCUSSION

Forest site quality evaluation is a vital part of a complimentary framework that also involves yield prediction and forest land classification (Figure 6)(Carmean 1977). Each of these three broad fields have a common goal: to estimate and classify the productive capacity of forest land for growing trees. Those concerned with yield prediction need means for identifying the specific land locations where yield tables and growth and yield models are applicable. Thus, mensurationists require means for identifying local site quality as well as site quality for larger areas such as working circles and other management units. Those concerned with forest land classification also need means for determining both site quality and potential yield for each soil or ecosystem unit defined in their classification system.

Finally those concerned with directly estimating site quality using trees, or indirectly using soil-site methods, need to link their site index estimates to yield tables and to growth and yield models. Also needed are means to link site index estimates to units used in soil or ecosystem classification systems. Estimating site index from an individual tree, or from a soil pit is only a site quality estimation for that particular point in the landscape.

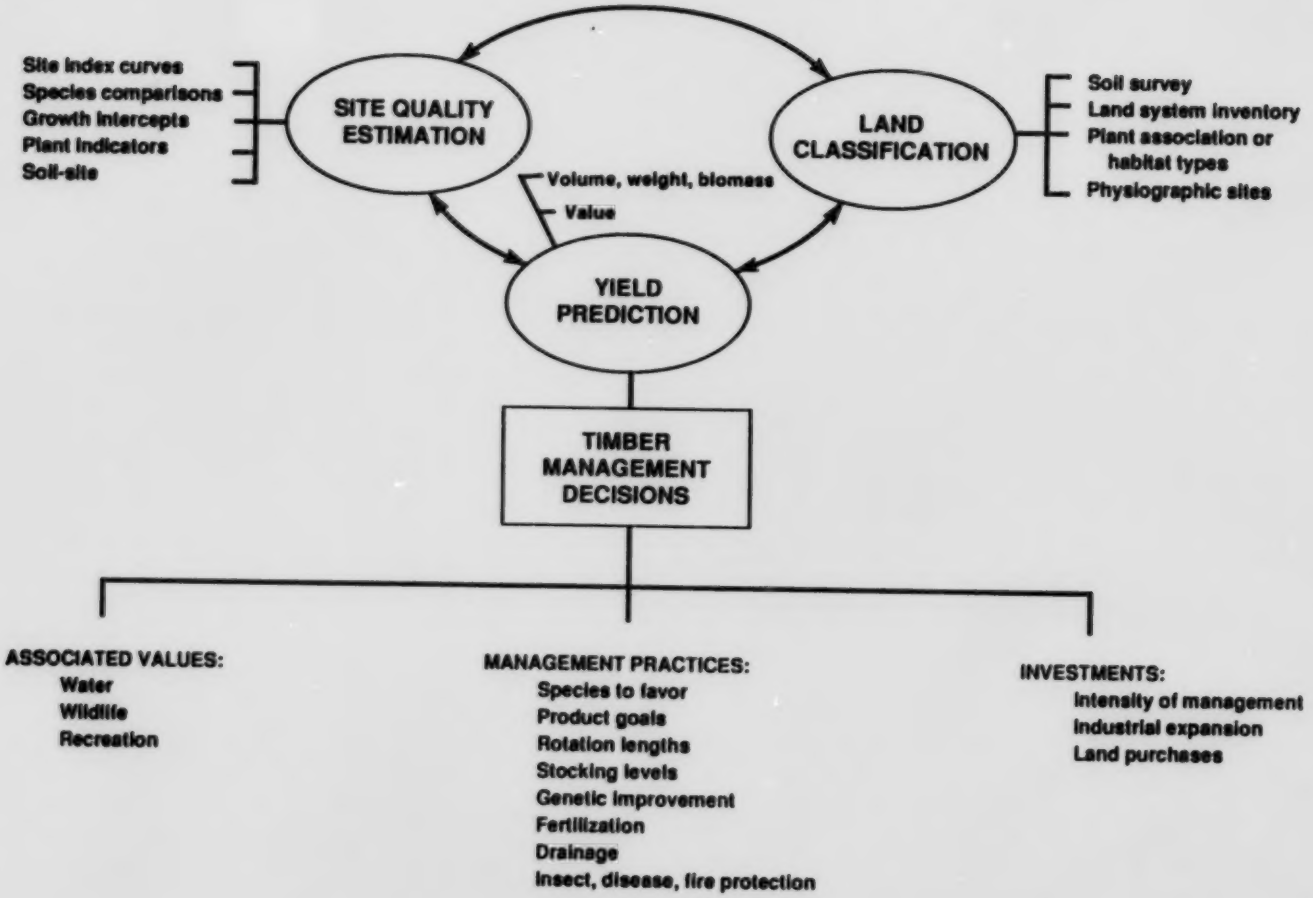

Figure 6. A complementary framework of site quality estimation, yield prediction, and forest land classification is needed for decisions about intensive timber management practices (Carmean 1977).

Methods are needed for combining these point estimations into site quality estimations for stands or larger management areas. Thus, units defined in forest soil or vegetal classification systems provide a means for abstracting point observations of site quality into a site quality and yield classification for the entire landscape. However, this goal can only be accomplished if units defined in the soil or vegetal landscape classification system are closely related to site quality, and if these defined units have relatively little internal variation in site quality. Broad soil and vegetal classification units that vary greatly in soil and topographic conditions also probably vary greatly in site quality. Thus, such broad and variable classification units will have limited value for classifying site quality or potential for tree growth and yield.

Direct methods (Table 2) for estimating site index can be used for monitoring relationships between forest site index and units defined in soil and ecological classification systems. If wide variations of site index occur within these units then specific soil and topographic features identified by soil-site studies can be used for refining or redefining these broad and variable units. For example, our jack pine soil-site studies show that soil depth and soil coarse fragment content are features closely related to site index of jack pine. Accordingly, these specific features can be useful for refining or phasing soil or ecological units thus attaining units having minimum variations in site quality.

Forest site quality, as with agricultural land productivity, is not a fixed and unalterable feature of the landscape. Thus forest site quality can be maintained, can be enhanced, or can be degraded. When we estimate site index we are in effect looking backward in time, i.e., our site index estimate is based on tree height growth for the past 50 years of time. However, past tree growth is no guarantee that future tree growth will continue to be similar.

Site quality for certain areas can be improved by practices such as fertilization, drainage, irrigation, or by establishing

nitrogen-fixing vegetation. Many of these advanced practices are already used in forest regions where intensive forestry is being applied. In contrast, site quality for certain areas can be degraded by soil compaction and erosion, and by excessive nutrient loss associated with severe fires, short rotation biomass harvesting, and full-tree harvesting that removes nutrient-rich tree crowns from the area. Site quality can also be degraded using heavy mechanized harvesting equipment on sensitive soils, or by severe site preparation that removes slash, litter layers and surface soil layers. Effects of these unwise practices on site quality degradation are now being recognized and, hopefully, forest management practices will be adopted that will avoid or diminish site quality degradation (Utzig and Walmsley 1988).

Extensive forest management will generally be practised on much of the forest land of northern Ontario in the foreseeable future. Most of these lands will be managed on long rotations, only merchantable portions of merchantable trees will be removed, and intensive practices such as fertilization and drainage will only be applied to selected local areas. Accordingly, northern Ontario forest soils will be relatively unchanged except for occasional areas where unwise harvesting and site preparation cause physical and chemical soil degradation. For these extensively managed forest lands, site quality methods developed from studies of natural stands probably will be applicable to most of the new natural forest that follows harvesting of present natural stands.

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PRELIMINARY SITE QUALITY KEYS FOR ESTIMATING PRODUCTIVITY ON BLACK SPRUCE AND JACK PINE SITES IN NORTHWESTERN ONTARIO

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ABSTRACT

Direct and indirect methods of estimating site quality are defined in relation to their use for estimating jack pine (Pinus banksiana Lamb.) and black spruce (Picea mariana (Mill.) B.S.P.) site productivity on northwestern Ontario sites. The development of site quality keys for black spruce and jack pine are explained and use of the keys is detailed with reference to applications to yield tables, potential problems and limitations. The most important soil characteristics to consider when estimating site quality of jack pine and black spruce indirectly are depth, moisture regime and texture.

INTRODUCTION

There are various methods of determining site quality in the field, as pointed out by Dr. Carmean (1989) in his talk on 'What makes a site productive.' If a well stocked, mature stand of the desired species is available, site quality can be estimated directly. Direct measurement refers to using the trees themselves as indicators of site quality. Height and age measurements of the stand are used as inputs to site index equations or are compared with site index curves, where site index refers to height in metres at breast height age 50. For example, using Lenthall's (1986) site index curves for jack pine (Pinus banksiana Lamb.), we can estimate the site index of a stand of breast height age 70 with a dominant height of 18 m as being about 15 m at breast height age 50 years (BHA 50) (Figure 1).

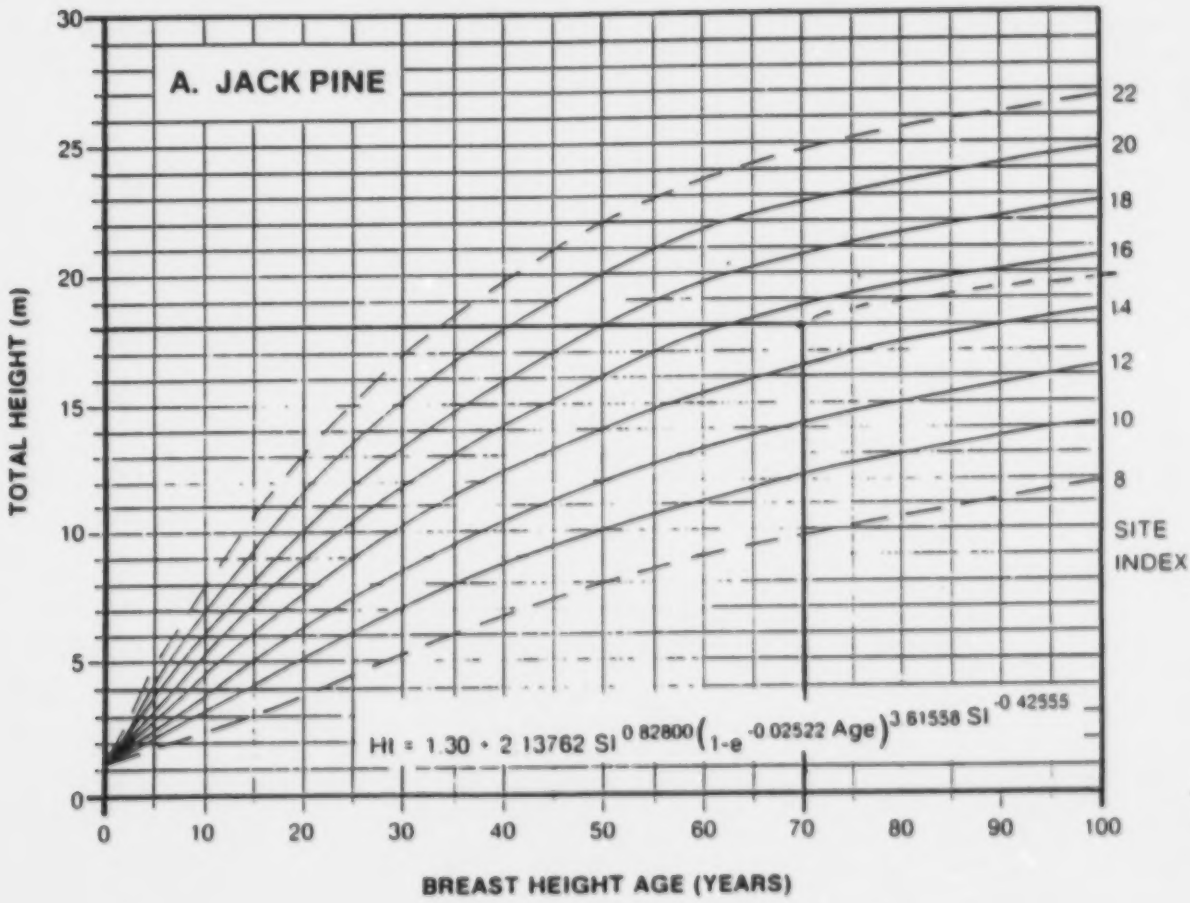

Figure 1. Jack pine site index curves (Lenthall 1986).

In the event of a cutover, presence of a different species or a poor stand on the site of interest, alternative methods of determining site quality are necessary. In such cases, features of soil, vegetation or topography can be used to estimate site quality indirectly. Use of indirect methods is restricted to areas where relationships between site quality for a given species and other features such as soil characteristics are understood and have been quantified in some way. In the past, researchers have established relationships between soil, topography and site quality for various species, but the equations were complex or the variables used in the equations were not easily measured in the field. For example,

equations developed for black spruce (Picea mariana (Mill.) B.S.P.) in Newfoundland included such variables as carbon to nitrogen ratios and available phosphorous (Page 1976). Not very useful to the field forester!

This paper will focus on the 'how to' of using indirect methods to estimate site quality for black spruce and jack pine in northwestern Ontario and introduce preliminary site quality keys, developed by the Northwestern Ontario Forest Technology Development Unit, for black spruce and jack pine site quality estimation.

FIELD DETERMINATION OF SITE QUALITY

Black Spruce

Black spruce is a species of wide ecological amplitude growing on almost all combinations of soil texture, depth and moisture. In this study, black spruce site quality was evaluated in relation to Forest Ecosystem Classification (FEC) soil types (Figures 2 and 3) (Sims et al. 1989). Despite the variability within soil types, some general trends were evident. Black spruce height growth was poor on the wet, stagnant organic sites and the extremely shallow, dry sites.

The sites were stratified into organic, peaty phase mineral and mineral soils to determine if specific relationships could be found. On organic sites, soil moisture regime and microtopography were found to be negatively correlated with site index, i.e., the wetter the site and the more mounding present, the poorer the site. On the other hand, the presence of alder (Alnus sp.) and moving water increased the quality of organic sites for black spruce. Water movement (as opposed to stagnant) results in better aeration and perhaps better nutrient availability. Alder is probably an effect of better site quality rather than a cause; that is, it occurs only on the better sites.

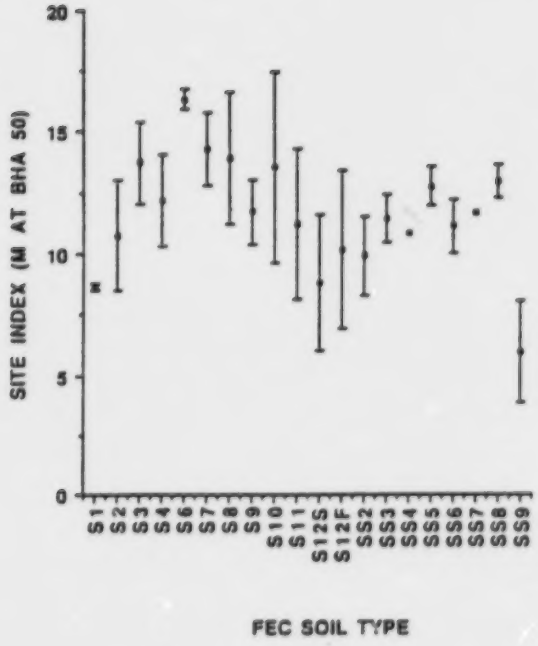

Figure 2. Black spruce site index by FEC soil type for the North Central Region.

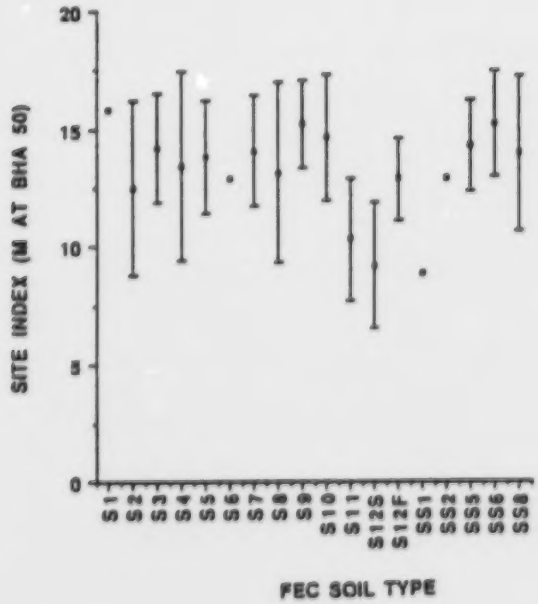

Figure 3. Black spruce site index by FEC soil type for the Northwest Region.

On the peaty phase mineral soils, the thicker the humic organic layer, the lower the site index. As on the organic sites, mounding was found to decrease site index. Increasing percent clay in the B horizon (as estimated from soil texture) had a positive effect on site quality for black spruce on peaty phase sites.

Mineral soils were found to be highly variable. The most important factor is texture, although telluric (downslope movement of nutrient enriched) water increases site index and impeded drainage decreases it. Silty clays, clay loams, silty loams and silty clay loams, the finer textured soils, are best for black spruce height growth. For example, Fort Frances district, which is off the Canadian shield and has lacustrine parent material from Glacial Lake Agassiz lake bottom, had site indices greater than 12 (BHA 50) on all 13 sites sampled. In comparison, the average site index of sample plots across the Northwest Region was 13 m (BHA 50) and across the North Central was 11 m (BHA 50).

A preliminary site quality key for black spruce (Figure 4) was developed for the Northwest Region based on a sample population of 81 plots. The preliminary site quality key conforms to FEC soil types for the organic and extremely shallow sites but excessive variability within soil types precluded the development of a key based solely on FEC types. Texture became the most important criteria for separating the sites. The key is preliminary because it is based on a small sample and has not been verified. That will be the job of the field foresters. The key also needs to be checked against data from the North Central Region so it can be applied across northwestern Ontario.

In summary, the best sites for black spruce are fresh to moist, loamy or clayey sites (fine textured soils) with greater than 30 cm of soil.

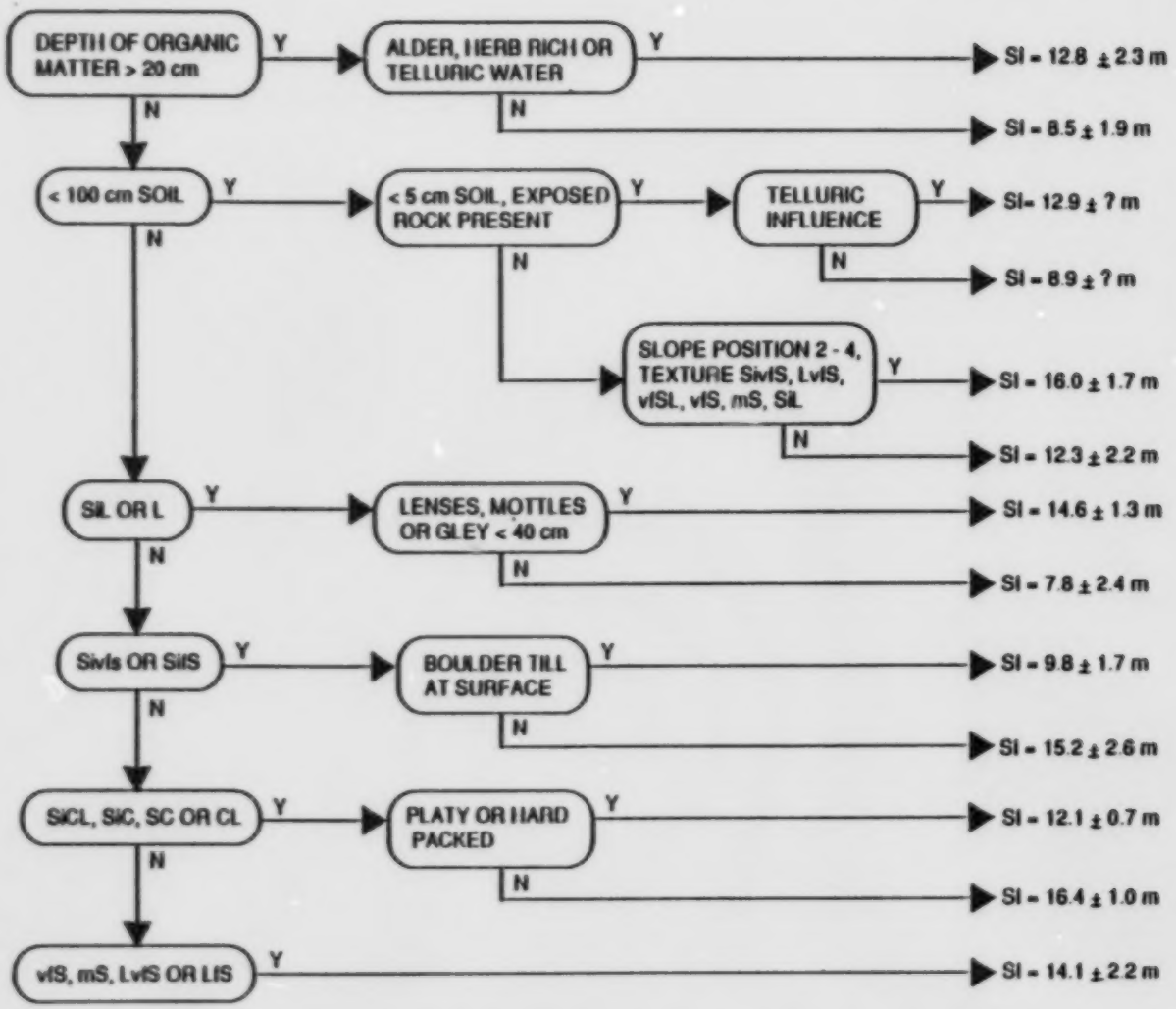

Figure 4. Preliminary site quality key for black spruce in the Northwest Region.

Jack Pine

All available site classification systems were tested in order to create a site productivity key for jack pine in the North Central Region. The three available site classification systems were: 1) FEC soil types (Sims et al. 1989); 2) Schmidt and Carmean's (1988) site index prediction tables and equations; and 3) the Northern Region prime land key (Nicks 1985). Combining FEC soil types of similar moisture regime and texture yielded soil groups with significantly different average site index values at a 95% confidence level, using a student's 't' approximation test. Figure 5 depicts a statistical comparison between combined FEC soil groups. Most soil groups were statistically different.

The plot scatterings and descriptive statistics for each soil group are shown in Figure 6. Note the variation within versus between each soil group. The shallow soil types (SS3 and SS6) were subdivided into two populations. FEC soil type SS3 is defined as shallow soil between 5 and 20 cm deep. Those plots with high site indices were found to be at the bottom of slopes greater than 5%. The increase in growth may be from water and nutrients moving from upslope (telluric influence). Thus, soil group SS3 was subdivided into two statistically different populations: 1) sites without telluric influence (SI = 10.2 m); and 2) sites with telluric influence (SI = 15.5 m). Likewise soil type SS6 had outliers with very low site index. Soil type SS6 is defined as soil 20 to 99 cm deep. It was found that plots with low site index all had soil less than 30 cm deep. Soil type SS6 was subdivided into two statistically different populations based on soil depth: 1) soil 20-30 cm deep (SI = 11.5); and soil 30-99 cm deep (SI = 15.9).

These statistically different soil groups were then used to create two jack pine site productivity keys. The first key is based on combined FEC soil types (Figure 7), while the second key is based on soil features independent of the FEC types (Figure 8). For each soil group an average and range is given for site index.

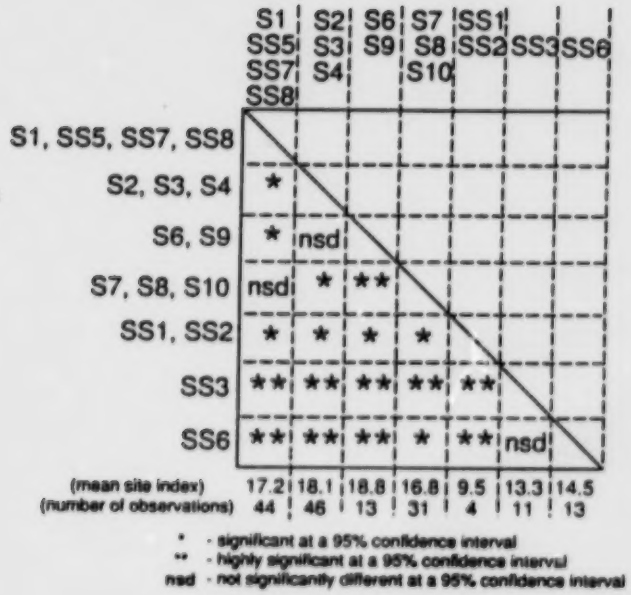
S1 SS5 SS7 SS8
S2 S3 S4
S6 S9
S7 S8 S10
SS1 SS2
SS3
SS6
S1, SS5, SS7, SS8
S2, S3, S4
S6, S9
S7, S8, S10
SS1, SS2
SS3
SS6
nsd
(mean site index) 17.2 18.1 18.8 16.8 9.5 13.3 14.5
(number of observations) 44 46 13 31 4 11 13
* - significant at a 95% confidence interval
** - highly significant at a 95% confidence interval
nsd - not significantly different at a 95% confidence interval

Figure 5. Student's 't' summary of combined FEC soil types by depth, moisture regime, and family particle size.

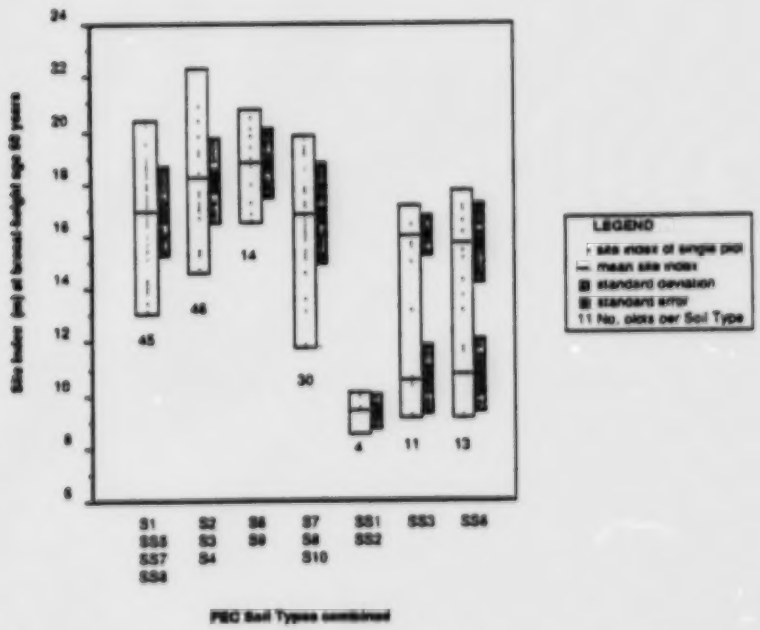

Figure 6. Plot scatterings and descriptive statistics for combined FEC soil types for jack pine in the North Central Region.

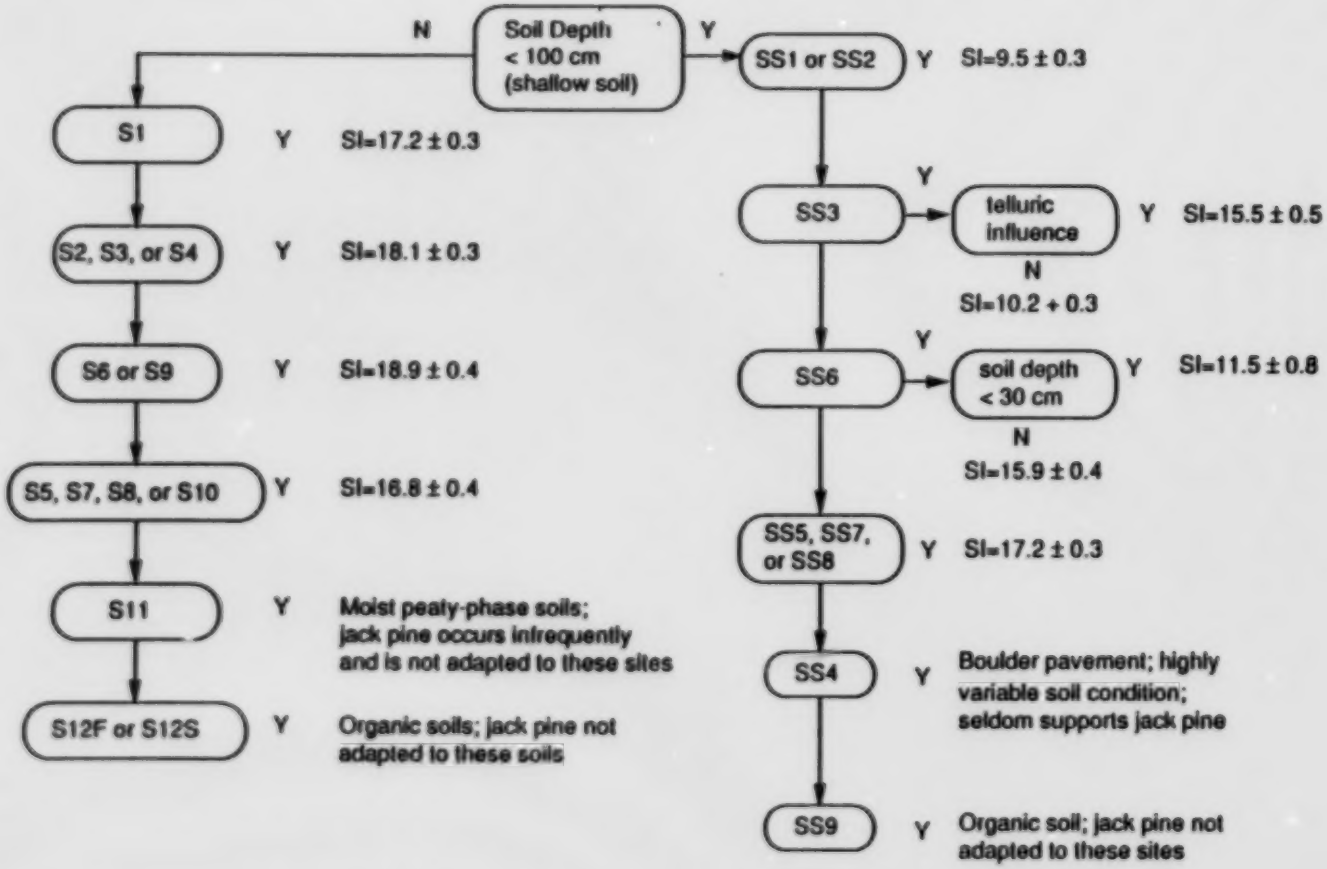

Figure 7. Jack pine site productivity interpretation key by FEC soil types.

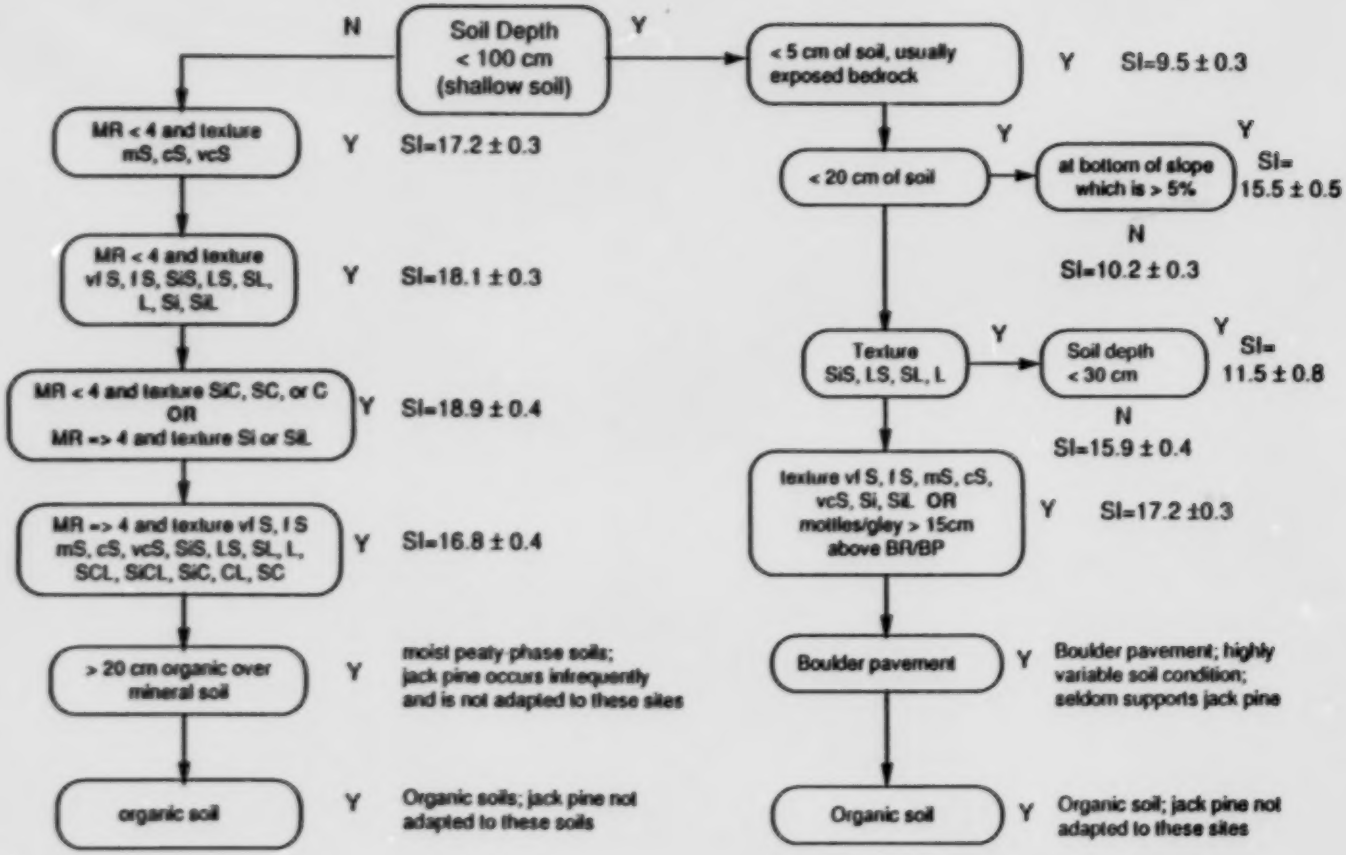

Figure 8. Jack pine site productivity interpretation key by soil characteristics.

One of the conclusions of this study was that height growth (productivity) of jack pine is related to three variables: 1) soil depth; 2) moisture regime and 3) texture. All three of these are part of FEC soil keys and the Ontario Land Inventory maps (Anon. 1977). It should be noted that these characteristics may not directly influence the height growth of jack pine, but instead are indirect influences. Soil depth, moisture regime and texture probably influence moisture and nutrient relationships which directly affect jack pine height growth. The three soil variables are also interrelated and influence one another.

The best sites for jack pine in the North Central Region were found to be fresh sites with loamy or loamy-clay soils, deeper than one metre. This is based on 183 sample plots distributed across the region.

Moisture regime had a large influence on height growth of jack pine. An earlier soil-site study, done across northern Ontario (Chrosciewicz 1963), also established that moisture regime influenced jack pine height growth. Height growth increased from dry to moister sites up to fresh sites (Figure 9). Although fresh sites are the most productive for jack pine, natural jack pine stands occur there the least, probably due to high competition (Figure 10).

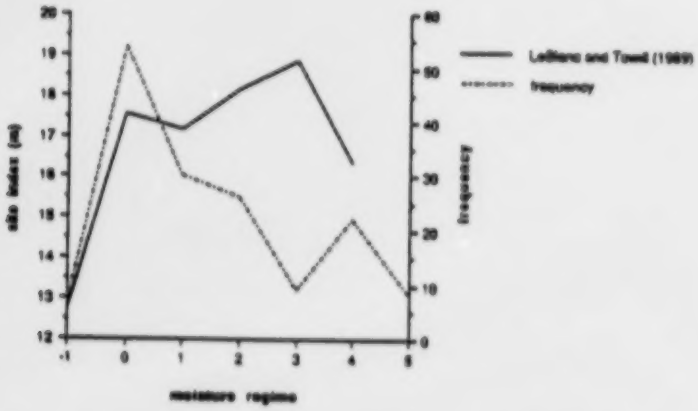

Figure 9. Site index for jack pine and frequency of occurrence on soils of varying moisture regimes.

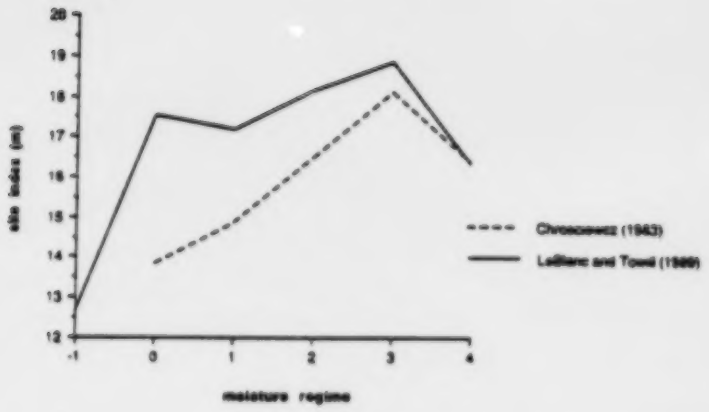

Figure 10. A comparison of North Central Region jack pine site index versus moisture regime with that found by Chrosciewcz (1963).

RELATING SITE QUALITY TO PRODUCTIVITY - THE APPLICATION OF YIELD TABLES

How can site index and site productivity be related to stand volume, which is, after all, what the forester is interested in? Soils are easily related to site index using the site quality keys (Figures 4,7,8). Site index can be related to stand volume using yield tables. The predicted stand volume can in turn be used to make decisions on species selection by site, volume comparisons between sites, whether productivity warrants intensive management and economic calculations for different management strategies.

As an example, assuming jack pine is the species of interest, once the soil features are determined and site quality is estimated from the key, a yield table for that site index is used to estimate volume. Currently, yield tables presented by Willcocks et al. (1989) are for site index 12, 15, and 18. Using FEC soil type SS5 (moderately shallow and sandy soil), the estimated site index for jack pine is 17.2 m (BHA 50). The site index 18 yield table (similar to Plonski's site class I) indicates an estimated yield of 295 m^3/ha at breast height age 50 years (Figure 11), roughly 57 years total age. With variable density yield tables maximum density is assumed for natural stands.

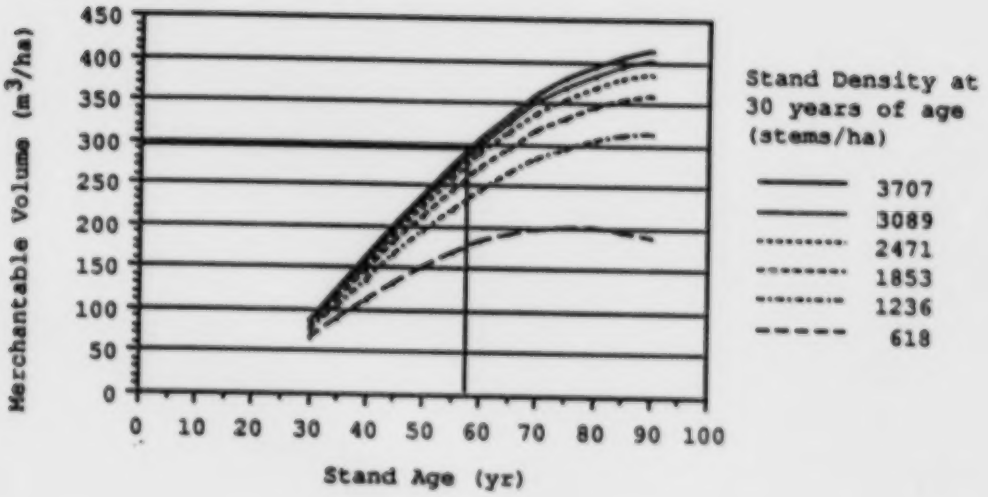

Figure 11. Variable density yield curves for site index 18 jack pine.

PROBLEMS

The first major problem relates to soil variability across a site. A single sample is often not adequate to determine the soil characteristics of an area and in many cases more than a single soil condition will exist across a block making some integration of interpretations necessary. Before deciding on productivity and relating this to potential volume, it is very important that an accurate analysis of the site conditions has been made or erroneous predictions will result.

The possibility also exists that soil productivity will change after harvesting. The impact of compaction, water table adjustments, etc., need to be taken into account when assessing productivity potential.

When relating single tree productivity to volume, stand density can have a great effect on the final production on a given site. This must be considered in advance. Since most yield tables are for total height age whereas site index curves are for breast height age, problems can arise when going between the two.

SUMMARY

Determining the most productive site for jack pine and black spruce in northwestern Ontario is possible through the use of site quality keys developed by the Northwestern Ontario Forest Technology Development Unit. The most important features to look for are soil depth, soil moisture and soil texture. Black spruce will do better than jack pine on the shallower and wetter sites but on good upland sites jack pine will generally outproduce black spruce.

More work is required to more accurately establish black spruce predictive keys but an important link has been made between soils, site index and yield predictions. The productivity of cutovers, non-satisfactorily regenerated areas, and immature stands can now be quantitatively assessed, easing future management decisions.

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Northwestern Ontario's Forest Ecosystem Classification: Concepts and Choices[1]

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ABSTRACT

An extensive program of site classification has been conducted within mature, harvestable forests of northwestern Ontario over the past several years. The Northwestern Ontario Forest Ecosystem Classification (NWO FEC) has evolved into a simple and easy-to-use field system for recognizing and naming forest ecosystems.

The NWO FEC program and related activities are providing a series of tools for improved forest management planning in this part of the province. Some main components discussed here are: derivation, development and testing of the NWO FEC system; related technology-transfer activities; development of NWO FEC-related forest management interpretations; pilot NWO FEC mapping and photo interpretation studies; and other related research studies.

INTRODUCTION

Forest ecosystems are the forest/landscape units that forest resource managers must deal with during the planning and implementation stages of management. Forest ecosystems provide a basis for integrated, multiple-use resource management that weighs wildlife, recreation and other concerns along with timber harvesting. If management knowledge and experience are to be organized, communicated and used effectively, a clear and practical system for classifying these ecosystems is necessary.

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[1] Adapted from a paper previously prepared for Proc. 70th Meeting, Woodl. Div., Pulp and Paper Assoc. Can., Montreal, P.Q., March 1989.

Site classifications provide an important level of consistency and precision; in using such a system, individuals can all follow a similar decision process and use similar reasoning in identifying a site. Ecologically-based site classifications provide users with a "holistic" capability so that many important site parameters are weighed and considered together. These parameters may not all have to be individually assessed or compared.

Northern Ontario's forests are characterized by tremendous variability, often over relatively short distances. A site classification system that simplifies ecological and silvicultural relationships is essential for more intensive forest and resource management. Climate, understory vegetation, soil and other physical site features play important roles in determining how the forest ecosystems of northern Ontario evolve and develop (Hills and Pierpoint 1960, Hills 1961).

Forest Ecosystem Classification (FEC) was first undertaken in the Clay Belt of northeastern Ontario (Jones et al. 1983, Jones 1987). An FEC system is under development for sites that support red and white pine stands in the Algonquin Region of central Ontario (Merchant et al. 1989). The Northwestern Ontario FEC is providing the necessary framework for improved communication among forest managers in the North Central and Northwestern regions (Figure 1).

Since its outset, a major goal of the Northwestern Ontario Forest Ecosystem Classification (NWO FEC) has been to provide foresters and others working in the Region with a common and simple language for understanding and describing forest sites. Given the size and value of the forest resource, and the escalating commitments to silviculture and reforestation, there is an ongoing need to improve and intensify forest management in northwestern Ontario. This paper provides an overview of recent NWO FEC activities.

Figure 1. Northwestern and North Central Regions showing the geographic area studied in the NWO FEC program.

THE NWO FEC SYSTEM

Cooperative FEC studies were first initiated in the North Central Region jointly by the Canadian Forestry Service (now Forestry Canada-Ontario Region, FCOR) and the Ontario Ministry of Natural Resources (OMNR) in 1983; in 1985, the work was extended into the Northwestern Region. The program is still conducted jointly by OMNR and FCOR staff. There has been funding assistance for the work through the Canada-Ontario Forest Resource Development Agreement (COFRDA). Field program support by industry, the Great Lakes Forestry Centre, and OMNR's North Central and Northwestern regions and districts has also been provided. For the past two years, OMNR's Northwestern Ontario Forest Technology Development Unit (NWOFTDU) has assumed a key role in overseeing the NWO FEC program.

From the outset, the schedule called for completion of the NWO FEC during 1989-90 (Sims 1986, Sims et al. 1986). Several interim draft versions of the NWO FEC system have been developed and tested. Each summer, the classification was field tested by the researchers as well as by OMNR and industry foresters; such assessments led to numerous revisions and improvements. Fall and winter periods were then devoted to incorporating changes as well as new field data and updating various computer analyses and statistical summaries.

The NWO FEC system focuses on description and recognition of mature or harvestable forest stands and the soil/site conditions associated with these stands. In conducting the field program, attempts were made to sample systematically the full range of forest-site conditions that exist throughout northwestern Ontario. Different areas were visited during each of five field seasons from 1983 to 1987. Field testing of the classification during two summers (1986 and 1988) was conducted with a much broader sampling network so that geographic areas that were previously unsampled could be visited. The NWO FEC program has assembled a comprehensive database on natural forest stands in northwestern Ontario. Some 2,250 FEC plots were sampled, and full descriptions

of the general site, the soils, the vegetational composition and cover, and the forest stand were obtained. FEC sample plot information is organized and archived in computer files. (This database has already been an invaluable source of information for a number of other research and development studies.)

Although there were several interim versions, the NWO FEC system was derived in final form during 1988. Throughout the summer of 1988, final field testing was conducted in both regions. Material was subsequently finalized for formal publication of three field handbooks that detail the NWO FEC system (Baldwin and Sims 1989, Racey et al. 1989, Sims et al. 1989). Several scientific and technical articles related to the NWO FEC system have been completed (Sims and Towill 1988, Towill et al. 1988, LeBlanc and Towill 1989, Sims 1989, Wickware et al. 1989) and others, some of which are mentioned below, are in preparation.

MAIN NWO FEC CLASSIFICATION UNITS

There are 38 Vegetation Types and 22 Soil Types defined by the NWO FEC system (Table 1). Such diversity, however, would not be found in any one local area in northwestern Ontario. The NWO FEC system can be applied readily to a forest ecosystem in northwestern Ontario by individuals who have some basic knowledge of or training in plant identification and field description of forest soils. There is a two-stage allocation process:

Step 1. A forest stand is allocated to one of 38 Vegetation Types. To assist in the stand allocation process, a vegetation field key has been developed on the basis of the general overstory composition, modified as necessary by the presence/absence or general abundance of a few important understory plants.

Step 2. The soil is directly characterized in terms of a few critical parameters (e.g., moisture regime, texture of the parent material, depth to bedrock). Two field keys are provided: there are 13 S-Types (Soil Types with ≥100 cm of mineral or organic substrate) and 9 SS-Types (very shallow to moderately deep Soil Types with < 100 cm of mineral or organic substrate).

Table 1. Names of Vegetation and Soil Types described by the northwestern Ontario FEC system.

Vegetation Type

V1 ----- Balsam Poplar Hardwood and Mixedwood
V2 ----- Black Ash Hardwood and Mixedwood
V3 ----- Other Hardwoods and Mixedwoods
V4 ----- White Birch Hardwood and Mixedwood
V5 ----- Aspen Hardwood
V6 ----- Trembling Aspen (White Birch) - Balsam Fir/Mountain Maple
V7 ----- Trembling Aspen - Balsam Fir/Balsam Fir Shrub
V8 ----- Trembling Aspen (White Birch)/Mountain Maple
V9 ----- Trembling Aspen Mixedwood
V10 ----- Trembling Aspen - Black Spruce - Jack Pine/Low Shrub
V11 ----- Trembling Aspen - Conifer/Blueberry/Feathermoss
V12 ----- White Pine Mixedwood
V13 ----- Red Pine Mixedwood
V14 ----- Balsam Fir Mixedwood
V15 ----- White Spruce Mixedwood
V16 ----- Balsam Fir - White Spruce Mixedwood/Feathermoss
V17 ----- Jack Pine Mixedwood/Shrub Rich
V18 ----- Jack Pine Mixedwood/Feathermoss
V19 ----- Black Spruce Mixedwood/Herb Rich
V20 ----- Black Spruce Mixedwood/Feathermoss
V21 ----- Cedar (incl. Mixedwood)/Mountain Maple
V22 ----- Cedar (incl. Mixedwood)/Speckled Alder/Sphagnum
V23 ----- Tamarack (Black Spruce)/Speckled Alder/Labrador Tea
V24 ----- White Spruce - Balsam Fir/Shrub Rich
V25 ----- White Spruce - Balsam Fir/Feathermoss
V26 ----- White Pine Conifer
V27 ----- Red Pine Conifer
V28 ----- Jack Pine/Low Shrub
V29 ----- Jack Pine/Ericaceous Shrub/Feathermoss
V30 ----- Jack Pine - Black Spruce/Blueberry/Lichen
V31 ----- Black Spruce - Jack Pine/Tall Shrub/Feathermoss
V32 ----- Jack Pine - Black Spruce/Ericaceous Shrub/Feathermoss
V33 ----- Black Spruce/Feathermoss
V34 ----- Black Spruce/Labrador Tea/Feathermoss (Sphagnum)

(cont'd)

Table 1. (cont'd)

V35 ----- Black Spruce/Speckled Alder/Sphagnum
V36 ----- Black Spruce/Bunchberry/Sphagnum (Feathermoss)
V37 ----- Black Spruce/Ericaceous Shrub/Sphagnum
V38 ----- Black Spruce/Leatherleaf/Sphagnum

Soil Type

S1 ------ Dry/Coarse Sandy
S2 ------ Fresh/Fine Sandy
S3 ------ Fresh/Coarse Loamy
S4 ------ Fresh/Silty - Silt Loamy
S5 ------ Fresh/Fine Loamy
S6 ------ Fresh/Clayey
S7 ------ Moist/Sandy
S8 ------ Moist/Coarse Loamy
S9 ------ Moist/Silty - Silt Loamy
S10 ----- Moist/Fine Loamy - Clayey
S11 ----- Moist/Peaty Phase
S12F ---- Wet/Organic [Feathermoss]
S12S ---- Wet/Organic [Sphagnum]
SS1 ----- Discontinuous Organic Mat on Bedrock
SS2 ----- Extremely Shallow Soil on Bedrock
SS3 ----- Very Shallow Soil on Bedrock
SS4 ----- Very Shallow Soil on Boulder Pavement
SS5 ----- Shallow - Moderately Deep/Sandy
SS6 ----- Shallow - Moderately Deep/Coarse Loamy
SS7 ----- Shallow - Moderately Deep/Silty - Fine Loamy - Clayey
SS8 ----- Shallow - Moderately Deep/Mottles - Gley
SS9 ----- Shallow - Moderately Deep/Organic - Peaty Phase

A similar dichotomous approach to considering vegetation and soil information for the description of forest sites in northern Ontario was originally proposed by Hills and Pierpoint (1960; Figure 2). NWO FEC Vegetation or Soil Types are defined by sets of ecologically similar samples that have conditions ranging around "modal" descriptions. These descriptions are provided as a series of Factsheets in the field guide (Sims et al. 1989).

Once Vegetation and Soil Types are determined, a variety of forest management concerns can be addressed (e.g., Racey et al. 1989). The NWO FEC system provides a framework for organizing, overlaying and updating forest management interpretations. For example, it may be applied directly as part of an operational cruise or pre-cut assessment procedure (Towill et al. 1988) and it can be an important component of silvicultural planning.

Vegetation Types are keyed on the basis of dominant tree species and, at finer levels, on the basis of the presence/absence of or degree of cover by diagnostic understory plants. The system has close ties to the "working group" concept that most Ontario foresters are already familiar with (Arnup et al. 1988, Davidson et al. 1988). There are three main Vegetation Type groupings: hardwood and hardwood mixedwood, conifer mixedwood, and conifer.

Computer-based ordination analyses of the vegetational data helped define and stratify the 38 Vegetation Types (Figure 3). Ordination is a mathematical measure of the similarity/dissimilarity among units or groupings (Hill 1979, Gauch 1982); when viewed along the first two axes, relationships among types are displayed. The ordination axes may also be interpreted; for the NWO FEC vegetation data (2,250 stands X 910 vegetation species), the horizontal axis mainly represents a nutritional gradient, whereas the vertical axis is, from bottom to top, a wet to dry soil moisture gradient.

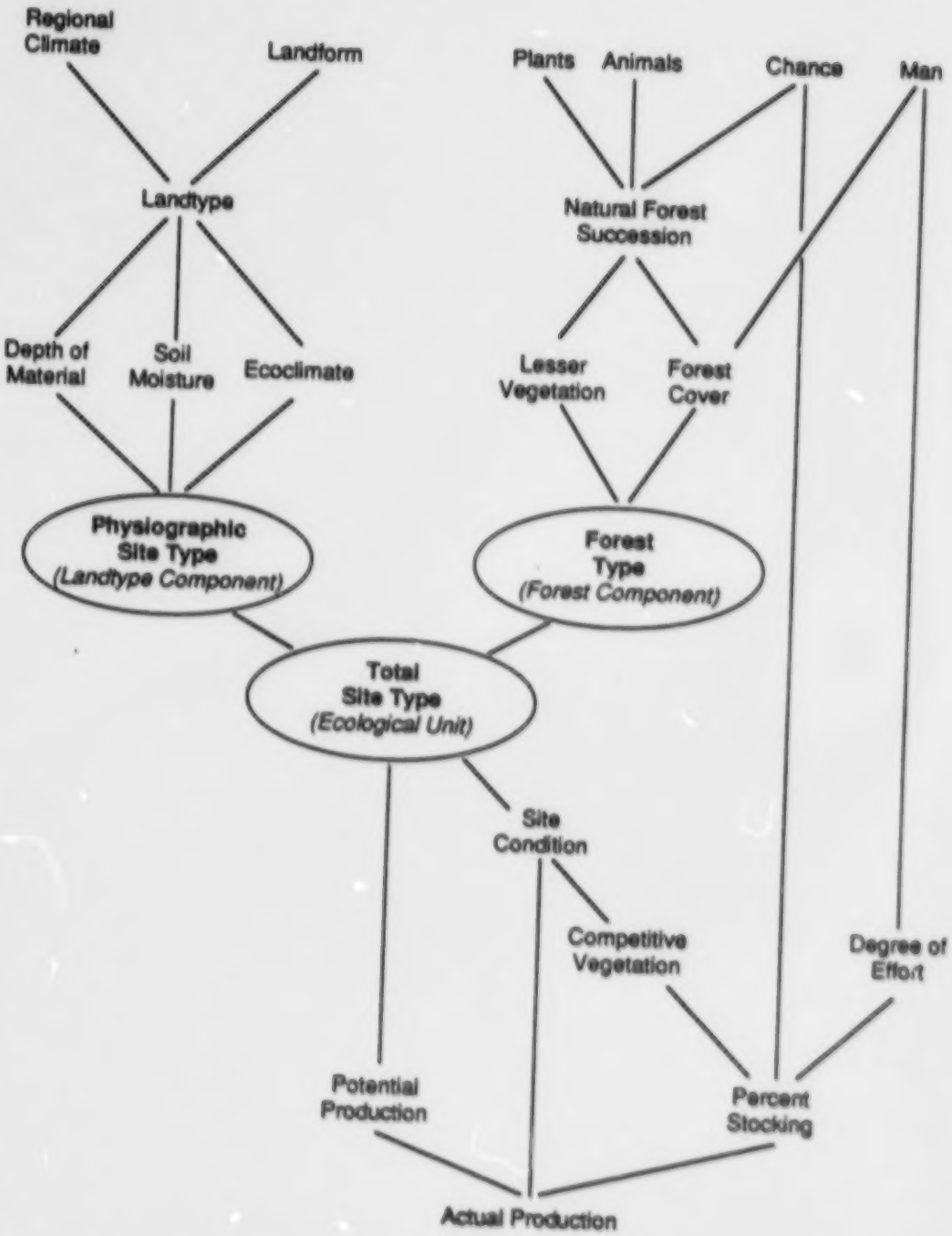

Figure 2. A conceptual framework for forest site classification in northern Ontario (from Hills and Pierpoint 1960).

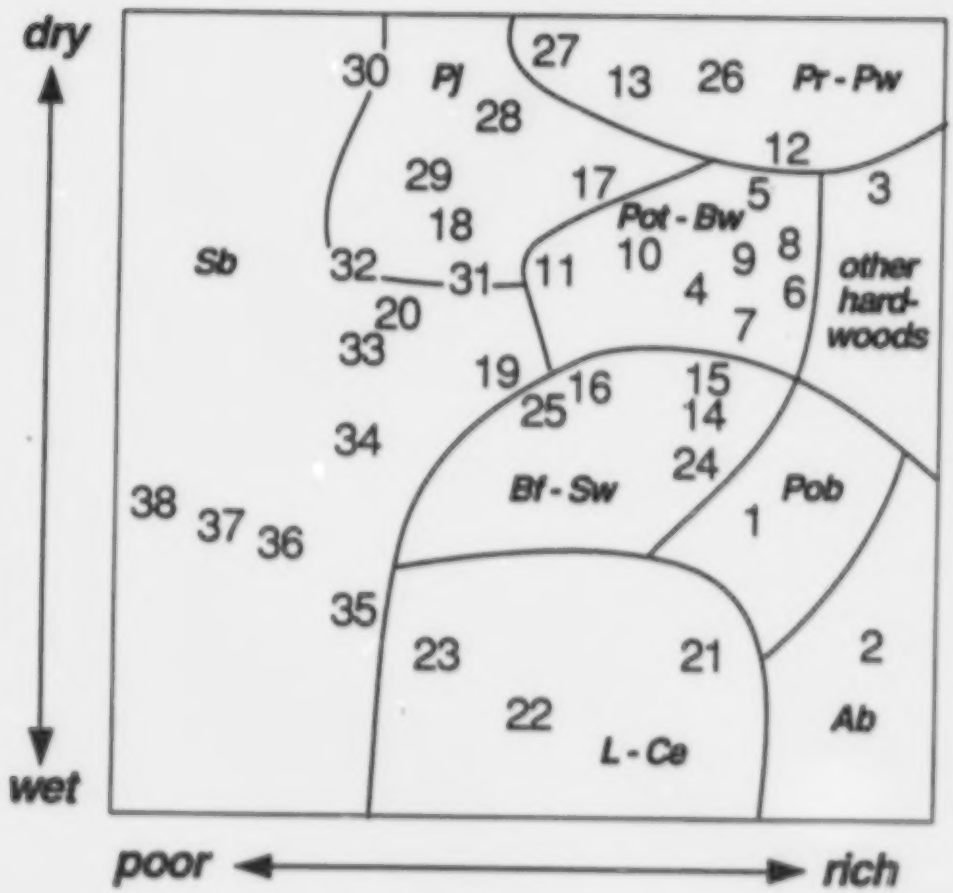

Figure 3. Ordination diagram of the 38 Vegetation Types, with dominant forest tree species overlain. Major environmental gradients are indicated along axis 1 (increasing nutrient status, from poor to rich), and axis 2 (changing moisture status from wet to dry).

As already mentioned, the Soil-Type key is divided into two parts, one that deals with deeper soils (≥100 cm deep) and one for shallower soils. Accurate Soil Type classification requires augering or digging of soil pits and quick examination in the field of a few important soil features. Many divisions of the key, for example, are based on a field assessment of soil texture. The main parameters used in the NWO FEC Soil Type key are the depth to bedrock, soil texture of the parent material, estimated soil moisture regime, and thickness of the organic layer (Bates et al. 1985). General trends for many of the soil parameters can be correlated readily with the NWO FEC Vegetation Types (Figure 4).

It is perhaps noteworthy that the major initial divisions of the NWO FEC system are not based directly on macroclimatic features. Most macroclimatic gradients vary gradually across northwestern Ontario. Sharp climatic changes, such as those elevational, topographic, and climatic gradients that are recognized in the biogeoclimatic classifications for British Columbia and Alberta (e.g., Krajina 1969, Klinka et al. 1979, Corns and Annas 1986), are not significant in northwestern Ontario.

During the analytical phases of the NWO FEC program, a number of climatically based stratifications were applied, including Hills' Site Regions (Hills 1961), but none provided a sufficiently clear or significant breakdown to be useful. Nonetheless, climatic features are important inherent components of northwestern Ontario forest ecosystems. Climatic information can be best incorporated into individual NWO FEC forest-management interpretations (Racey et al. 1989). For example, specific climatic variables can be important criteria for a wide range of potential interpretations, such as the selection of species and stock types, the determination of outplanting constraints and the prediction of the severity of frost damage (Comeau et al. 1982, Green et al. 1984).

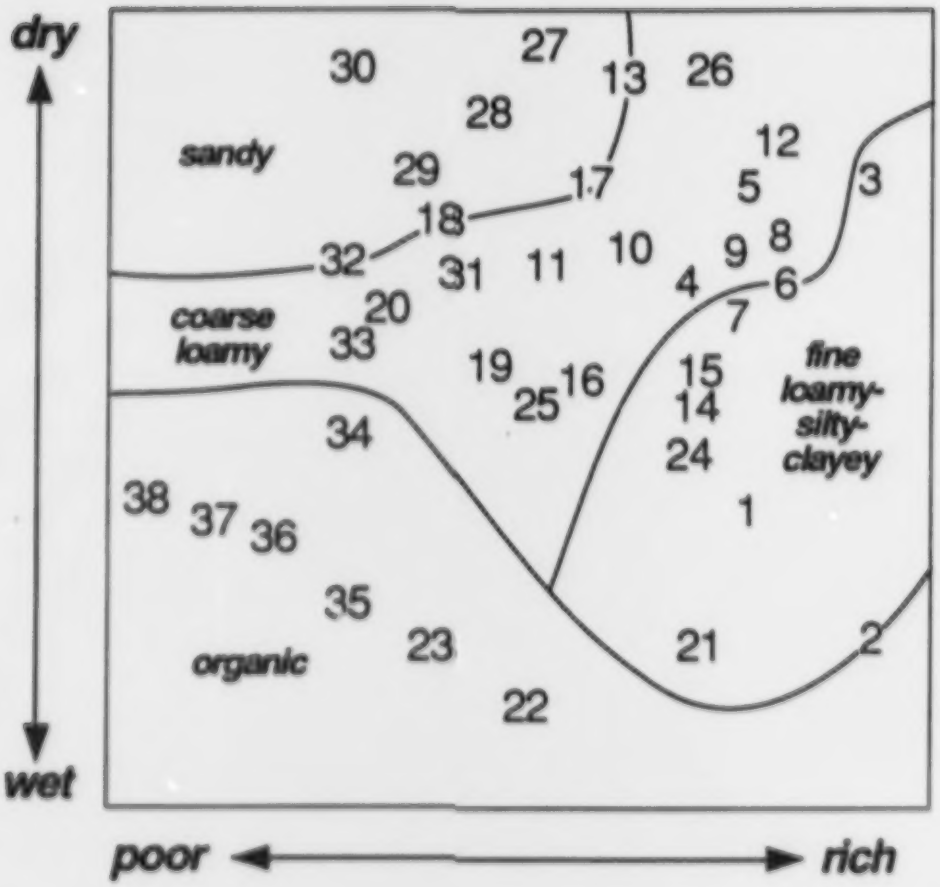

Figure 4. Ordination diagram of the 38 Vegetation Types, with main patterns of soil texture class overlain. Major environmental gradients are indicated along axis 1 (increasing nutrient status, from poor to rich), and axis 2 (changing moisture status from wet to dry).

TRAINING COMPONENT

So that practitioners can properly and consistently apply the classification in the field, some training and familiarity with the NWO FEC system is essential. Useful aids for applying the system to description of both soils and vegetation description are included in the NWO FEC field manual (Sims et al. 1989).

A series of 2- to 4-day field courses were put together, "packaged" and given to field staff during the summer and fall of the years 1985 through 1989. Course "packages" consist of: pre-course registration packages, prearranged field itinerary information (with driving directions, field notes and, in some cases, full soil analyses), sets of student handouts and instructors' notes, audiovisual materials and complete slide-tray sets, course response and evaluation forms, and printed "graduation certificates". Field and lab equipment and demonstration materials for use in the courses were also assembled. Three different courses were developed in this manner:

1. **Soils Description:** a 4-day introductory course that covers soil profile development, description of soil horizons, soil processes, use of the NWO FEC Soil Type key and Factsheets, and field assessment of soil texture, moisture, drainage and other parameters.

2. **Boreal Vegetation:** a 3-day field course that covers terms and concepts in plant ecology and taxonomy, ecology of major tree and competitive understory species, use of the NWO FEC Vegetation Type key and Factsheets, and field recognition of common boreal forest plant species, including soil/site "indicators".

3. **Soils/Landform Relationships:** a 4-day field course that covers the glacial history of northern Ontario, patterns and characteristics of common landforms, correlations of various soil features with landforms, recognition of landforms on the ground and on aerial photos, and interpreting landform information for forest management activities.

The courses are an important component of the NWO FEC program: basic skills required to apply the NWO FEC system are learned and practised. The student-to-instructor ratio is low (around 5:1), and the emphasis is on "hands-on" experience. The classroom

portion is kept to a minimum, usually no more than two half-day sessions. The three courses currently offered are registered with the provincial Human Resources Branch and OMNR staff who successfully complete a course are given formal accreditation.

Courses were offered at various dates and locations throughout the North Central and Northwestern regions. Course attendees included OMNR forestry field staff (including Unit and Forest Management Agreement foresters), industry silvicultural staff, federal research staff, and others; in 1988 alone, there were about 220 attendees at the NWO FEC courses. Portions of the formal courses have also been provided for Lakehead University students during fall Field School over the last few years. For the past three summers, the course schedule has been prepared and monitored by staff of the NWOFTDU.

NWO FEC FOREST MANAGEMENT INTERPRETATIONS

Site classification researchers have recently been successful in integrating a wide variety of forest management interpretations into site classification systems (e.g., Comeau et al. 1982, Green et al. 1984, Corns and Annas 1986, Coates and Haeussler 1987, Kotar et al. 1988, Zelazny et al. 1989). The NWO FEC system is applicable at a variety of levels or intensities, and consequently should be valuable for different users in applications involving various forest management objectives. The NWO FEC should be an appropriate framework for a broad range of forest management interpretations (see also Racey, this proceedings).

A NWO FEC field manual (Racey et al. 1989) deals with a range of forest management interpretations for NWO FEC Vegetation and Soil Types. Various provisional interpretations are presented by means of several approaches (e.g., Factsheets, two-way tables and ordination overlays). These interpretations, and others reported elsewhere (e.g., LeBlanc and Towill 1989, Sims 1989, Wickware et al. 1989), will evolve over time as new information becomes available and as feedback and input from field staff is received and compiled. The following list suggests some potential areas in

which forest management interpretations could be developed in the medium and short terms with the NWO FEC system:

Medium Term:

- Prime site management of timber resources
    - timber management planning
    - strategic land-use planning
    - Class Environmental Assessment for timber management
    - wildlife habitat interpretation
    - integrated resource management
    - recreation and tourism planning

Short term:

- Timber harvesting
    - season of harvest
    - logging method/cut pattern
    - site operability
    - windthrow hazards
- Resource renewal and maintenance
    - soil/site degradation potential
    - site quality and productivity
    - vegetative competition potential
    - selection of planting-stock species
    - site preparation options
    - equipment selection
    - tending and release
    - habitat assessment
- Forest protection
    - area fire planning
    - insect and disease vulnerability
    - prescribed burning
    - forest fire behavior (fuel loading/ranking).

NWO FEC forest management interpretations should not supersede any knowledge gained by forest managers through systematic observation and experience -- <u>interpretations are intended as guidelines only</u>. When site-specific treatments are being planned, it is always preferable to evaluate sites individually and to revise or alter management interpretations as required. New developments and techniques will also dictate a need for periodic

updates and modifications to many forest management interpretations -- as practices and scientific knowledge evolve, so should the interpretations. A mechanism for obtaining field-level feedback on interpretations over the next few years, leading to revisions and expansions, has been implemented through the NWOFTDU. Interpretations should be valuable, for example, for interpretation of pre-cut survey information (Towill et al. 1988), and in updates of company and OMNR 5-year Timber Management Plans.

Towill et al. (1988) outline several steps in preparing for and undertaking a pre-cut survey incorporating the NWO FEC system:

1) organize background information, including maps, photos and other materials;

2) organize the work to be done by setting up the sampling strategy and design, conducting photo interpretation as necessary and assembling equipment;

3) prepare, in the field, to collect information according to the planned sampling scheme and match ground-sampling locations with aerial photos or a map base;

4) use prepared tally forms and follow some standardized data-collection procedure at points along survey lines or grids;

5) after the field program, collate and organize the information, and make forest management interpretations.

PILOT PHOTO INTERPRETATION AND MAPPING STUDIES

The NWO FEC system should be applicable for a number of different applications that involve photo-interpretation and mapping (including computerized geographic information system (GIS) applications). To investigate the potential usefulness and practicality of integrating the NWO FEC system with mapping and photo-interpretation, two pilot mapping studies were undertaken. Mapping that involves the determination of FEC units should also be complementary to prime-site-management strategies currently being considered for northwestern Ontario (Towill and Sims 1989).

Pilot NWO FEC mapping work was undertaken to test various techniques for mapping and identifying NWO FEC types on aerial photos. In 1987, a photo-interpretation and pilot FEC mapping program (at the 1:20,000 scale) was initiated for two 100-km^2 blocks, one northeast of Atikokan, Ontario and another east of Lake Nipigon. The two areas represent broadly different site conditions found in the North Central Region; the Atikokan area is primarily balsam fir (Abies balsamea (L.) Mill.) mixedwoods and jack pine (Pinus banksiana Lamb.) stands on a variety of surficial materials, whereas the Lake Nipigon area is strongly bedrock controlled and supports mainly black spruce (Picea mariana (Mill.) B.S.P.) stands.

Stratified sampling was employed on the basis of a combination of surficial deposit/landform information from airphoto interpretation, and Forest Resource Inventory (FRI) mapsheet polygons aggregated by major cover types. Field transects were sampled by three-person field crews for photo annotation and interpretation and collection of soil, vegetation and forest stand data.

Supplementary and FRI aerial photographs were acquired during the summer of 1987, and 1:15,840 photo-prints were annotated in the field. Data collected at over 1,600 stations along transects was subsequently summarized and analyzed. Draft maps (1:20,000 scale) of soil and vegetation types were completed; these are currently being field checked for accuracy. Work will be completed during the 1989-1990 season, and a GIS will be used for analysis, interpretive mapping and final map presentation. One component of GIS studies for the Atikokan map area is to develop modelling approaches for prediction and assessment of levels of susceptibility to spruce budworm damage.

OTHER RELATED ACTIVITIES

A variety of other activities related to the NWO FEC have been undertaken, including preparation of a field plant identification manual, and research studies on the ecology of competitive species, the autecology of major tree species, common toposequences, and the

distribution and preservation of black spruce advance growth. Some of the findings from the latter investigation have been summarized recently by Wickware et al. (1989); advance growth was studied within a number of vegetation types and, on the basis of measurements of percent stocking, a simple predictive model was developed.

The companion "plant manual" for the NWO FEC system has been completed (Baldwin and Sims 1989); this back-pocket guide uses simple terminology and provides diagnostic features for field identification of 157 common plant species. Line diagrams of growth habit, photographs and short NWO FEC-based habitat descriptions are included. Using the vegetation-type ordination, the manual clearly shows ecological distributions for many common plants of northwestern Ontario, including tree species.

Measurements of tree height, age, stocking, basal area and volume were collected at NWO FEC field plots. NWO FEC-related soil/site productivity studies are being undertaken (for example, see LeBlanc and Towill 1989). Development and revision of site index (SI) curves on the basis of NWO FEC plot information has been conducted along with additional stem analyses (Carmean 1987; Buse and LeBlanc, this proceedings). Collectively, these efforts should help define and clarify site-quality relationships among various NWO FEC vegetation and soil types for some of the principal commercial species.

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NORTHWESTERN ONTARIO'S FOREST ECOSYSTEM CLASSIFICATION FOR SITE-SPECIFIC MANAGEMENT

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INTRODUCTION

The Northwestern Ontario Forest Ecosystem Classification (NWO FEC) was developed between 1983 and 1989. The final publications **A Field Guide to the Forest Ecosystem Classification For Northwestern Ontario** and **Field Guide to the Common Forest Plants of Northwestern Ecosystem Interpretations** will be released in the spring of 1990. The Northwestern Ontario Forest Technology Development Unit has been, and will continue to be, involved in technology transfer of the NWO FEC through training courses, publications and the development of the forest ecosystem interpretations.

The NWO FEC provides a framework for describing vegetation and soils in an ecological context. Field staff and researchers alike have been very receptive to the NWO FEC, although there seems to be some confusion regarding how the classification will be applied and what benefits will be realized.

The purpose of this report is to introduce the concepts of forest ecosystem interpretations and treatment units, and discuss how they would be used in forest management.

INTERPRETATIONS

The verb interpret means, "To explain the meaning of; to make understandable." Therefore, when I talk about forest ecosystem interpretations for silviculture, I mean that each of the forest ecosystem types identified by the NWO FEC imply some limitations or opportunities for silviculture on those sites. In other words, for each significant vegetation or soil property, there are

consequences which relate to management; these consequences can be either good or bad.

A favourable consequence of a fine-textured soil with a moisture regime of five, such as an S-Type 8, would be high productivity for black spruce (Picea mariana (Mill.) B.S.P.). Bad consequences for the same soil type would be its high susceptibility to compaction, high levels of competition or low productivity for jack pine (Pinus banksiana Lamb.). Likewise, a positive consequence of a stand with the attributes of V-Type 7 would be that regeneration to aspen is readily attainable. A negative consequence would be the extent of aspen competition on these sites, if regeneration to conifers was the primary objective.

This illustrates the paradox of forest ecosystem interpretations. In one sense, an interpretation is the application of science to site-specific management. On the other hand, an interpretation may be no more than the organization of new or creative ideas on the framework of the NWO FEC. Finally, the distinguishing features of the site may be good or bad, depending on the management objectives for the site.

One example of an interpretation is soil erosion hazard. The soil factors that govern erodability are texture, slope, mode of deposition and the fraction of coarse fragments (Table 1). Note that some of the variables, such as the fraction of coarse fragments, slope, and mode of deposition, are not used by the NWO FEC for the determination of the S-Type. This points out another very important concept in the use and application of the NWO FEC. Other soil properties must also be determined at the same time that the data for the FEC is collected. Often, this additional data must be used in conjunction with the NWO FEC, for the assembly of interpretations.

Table 1. Sites and conditions influencing soil erosion hazard.

Soil Conditions	Site/Soil Classification	Slope (%)	Hazard Rating	Comments
Organic	S12F, S12S, SS9		Low	
Sand	S1, S3, S5, S6, S7	<10	Low	Hazard rating will be reduced.
Gravel, Clay	S8, SS5, SS6, S11	>10	Moderate	If soil particles are angular (morainal), particle sizes are variable, coarse fragment content >35%, or abundant surface organic layer is present.
Silty soil	S2, 24, S9, S10	<10	Low	
Very fine sand, sand, or shallow soils over bedrock	S11, SS1, SS2, SS3, SS4, SS7 SS8	>10	High	Rounded soil particles (fluvial) or extensive site disturbance will increase hazard rating.

At present, the NWOFTDU has produced a number of forest ecosystem interpretations for both silviculture and wildlife. The silvicultural interpretations include:

1. factors affecting competing vegetation;
2. limitations to herbicides;
3. site considerations for black spruce management;
4. site considerations for jack pine management;
5. site considerations for trembling aspen management;
6. soil erosion hazard;
7. frost heave hazard;
8. compaction and rutting hazard;
9. root rot risk; and
10. spruce budworm

The wildlife habitat interpretations developed by the NWOFTDU include:

1. moose habitat considerations;
2. marten and fisher habitat;
3. non-game bird communities;
4. caribou range suitability; and
5. white-tailed deer habitat.

The details of these interpretations will not be given in this report, as they are fully described in detail in the publication Northwestern Ontario Forest Ecosystem Interpretations (Racey and Whitfield 1989). The most important concept that needs to be implanted in the minds of users of the NWO FEC is that many values or consequences are predictable if we can develop an appreciation of known site factors. For instance, values of certain stands for moose can be identified by examining their vegetative characteristics or their species composition. Some stands offer good food production (Figure 1). Soil erosion can have major impacts on productive forest land, as well as fish habitat, but it is entirely predictable and avoidable when the risk can be identified in advance and appropriate management actions are taken to minimize this risk.

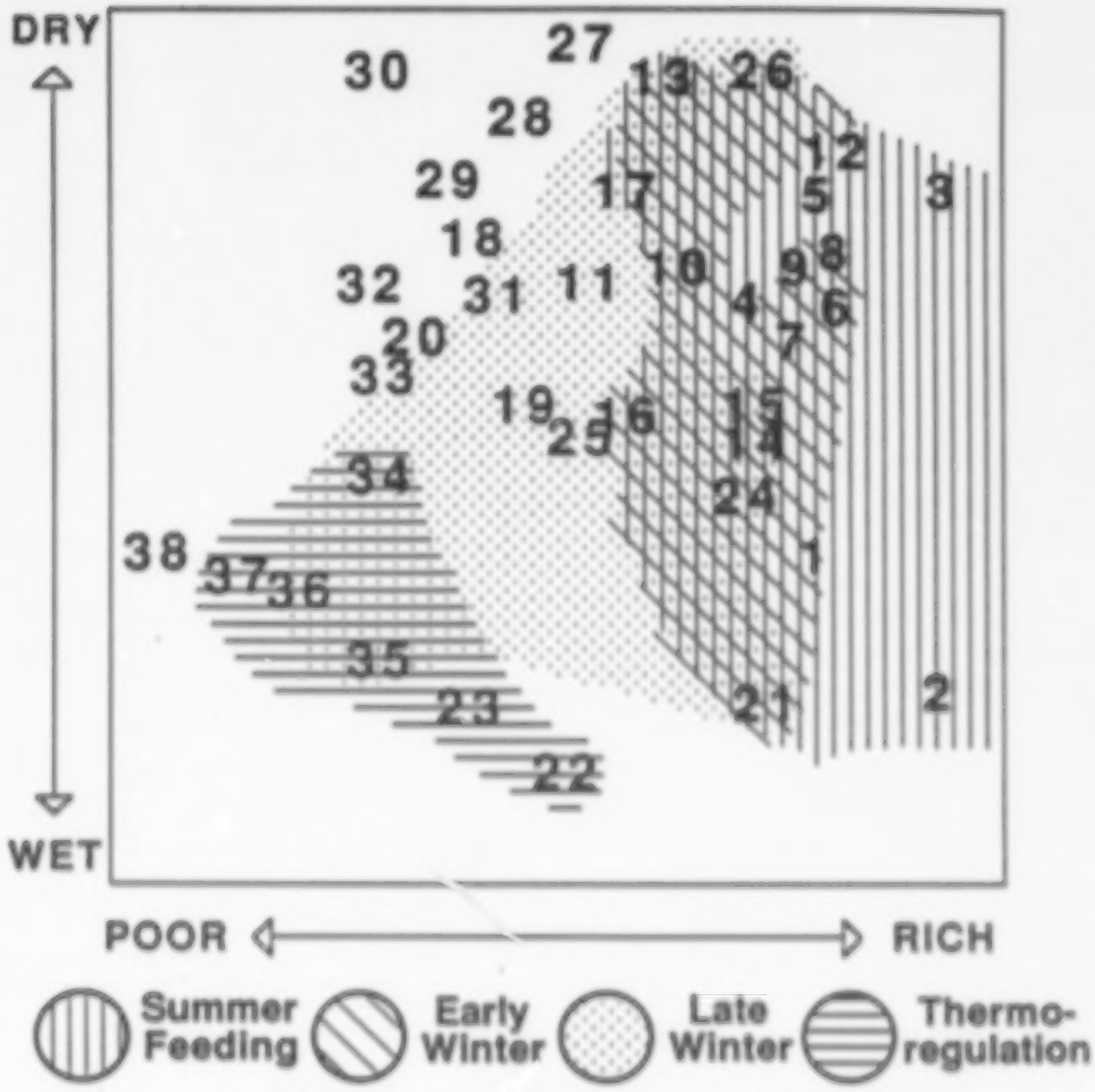

Figure 1. The NWO FEC vegetation types can be divided into groups which represent specific attributes for moose. Four major groups are stands which provide good browse production (summer feeding), good browse producing stands with good winter shelter (early winter), good winter shelter (late winter), and sites which are typical bedding areas for hot summer days (thermoregulation).

More interpretations will be assembled and published as time and funds permit.

TREATMENT UNITS

The key to applying the NWO FEC to management problems is in defining treatment units. A treatment unit is easily identified in the field and represents broad sites that support stands of similar tree species, productivity, soil, and understory vegetation. Stands within a treatment unit will respond similarly to a chosen silvicultural regime. In other words, treatment units are aggregations of soil and vegetation types to which a forest manager would apply the same prescription, use the same yield tables and receive similar results. When we examine a site for planning purposes, there is generally a minimum size of area on which we want to apply a discreet set of treatments, whether they be related to harvest, regeneration or tending. The treatments applied will depend on the vegetation and soil conditions on the site; these conditions, when put in terms of the NWO FEC, make treatment units a handy method for allocating silvicultural options.

Treatment units are part science, part intuition, and they must be defined in terms of management objectives for your management unit. They are developed by amalgamating soil types or vegetation types according to those factors having a direct impact on your management practices. We can divide up the V-Types according to products, moisture regime (Figure 2), soil texture (Figure 3) and ground cover. We can take any one parameter and map our management unit in terms of appropriate levels of any soil or vegetation property. These can also be translated into management values such as crop tree productivity, constraints to operability, intensity of competition, season of harvest, or preferred regeneration method. All of this can be done by intuition, common sense and an intimate knowledge of the NWO FEC.

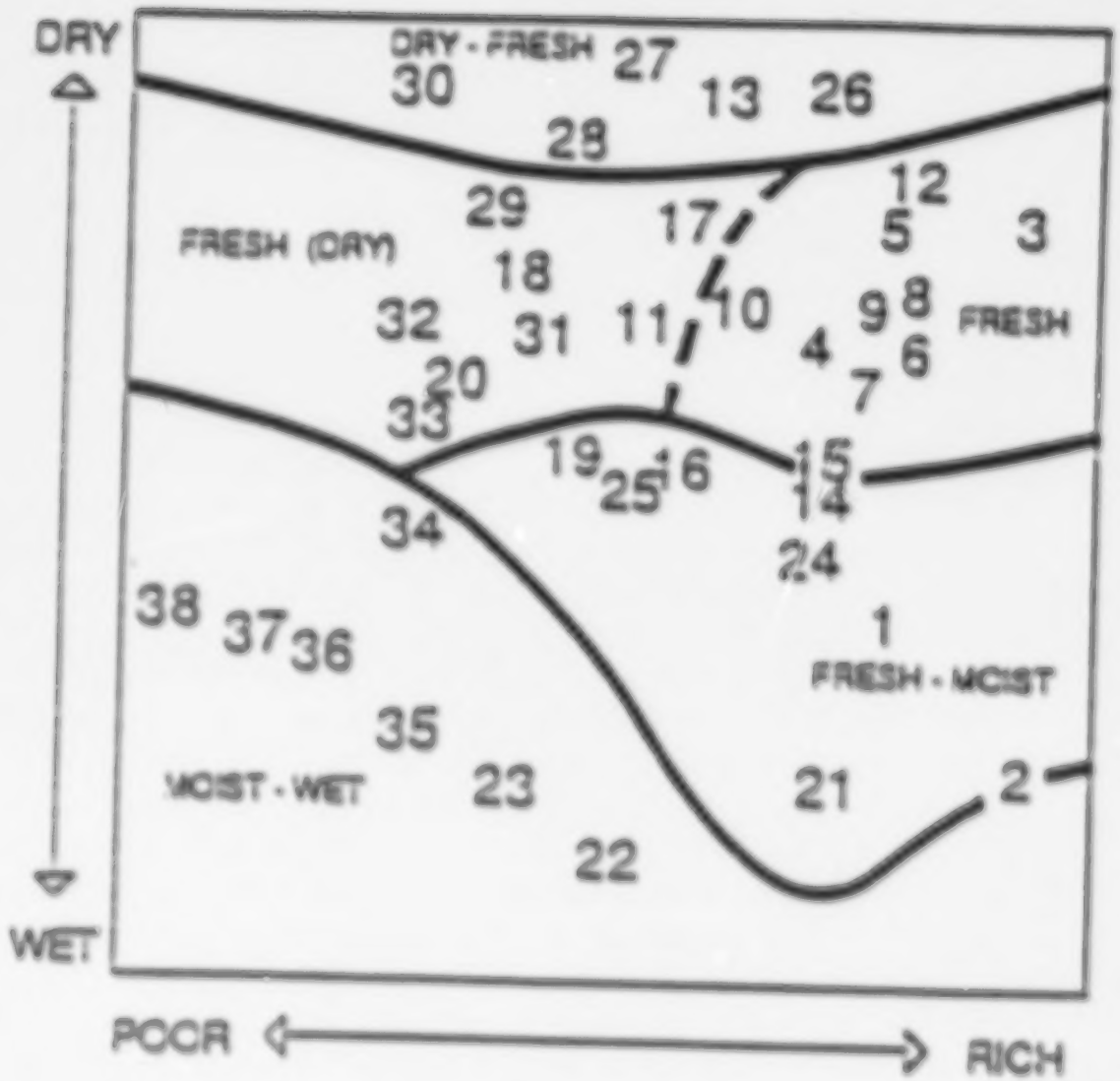

Figure 3. Typical soil moisture regimes for BWO FEC vegetation types.

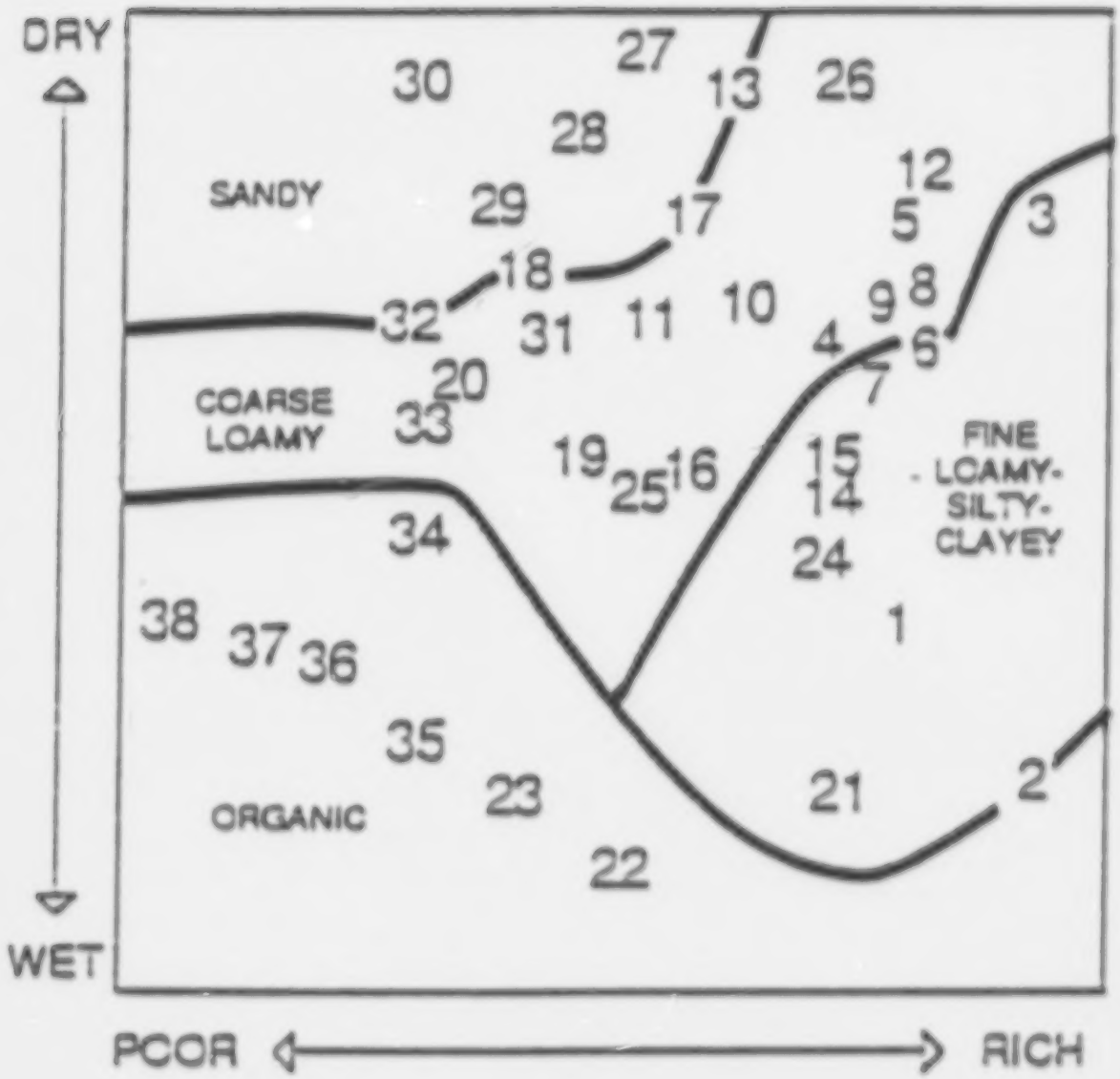

Figure 3. Typical soil textures for NWO FEC vegetation types.

I can't stress enough, the importance of making these decisions at the individual management unit level. We have assembled a set of 12 demonstration treatment units for northwestern Ontario, which can be used to show how to go about developing them (Racey and Whitfield 1989). Once again, I do not want to go into a lot of detail about something that is thoroughly covered elsewhere. Both the demonstration treatment units and the "how to" section on developing treatment units will be fully described in the NWO FEC interpretive guide.

Just as an example, I can describe treatment unit J (Figure 4). This unit poses a set of well defined limitations to silviculture.

1. Sphagnum, wet, mostly organic soils limit summer operability; will easily seed back to black spruce, which is the most suitable tree for this site.

2. This unit can be further broken down into a competitive phase, J1 (Figure 4), where extremely heavy competition can be expected from blue-joint grass (Calamagrotis canadensis (Michx.) Beauv.), speckled alder (Alnus rugosa (DuRoi) Spreng.) and raspberry. Chemical tending may be necessary. The other phase is less competitive; J2 (Figure 4) and chemical tending will probably not be necessary.

3. This unit can be readily determined from aerial photographs and assigned to the black spruce working group from the FRI.

Far more complex than this is treatment unit E, which, vegetatively, can be easily described, using aerial photographs and the FRI, as a black spruce - jack pine mixture, which may have occasional hardwoods, very poor shrub layer and feathermoss dominated ground cover.

1. This unit occurs on dry, fresh and moist soils, ranging from sandy to coarse loamy and silty soils.

2. There are three distinct phases, E1, E2 and E3, which are based on moisture regime and that have a great bearing on expected levels of competition, compaction and rutting risk, root rot susceptibility and, most important, crop tree productivity.

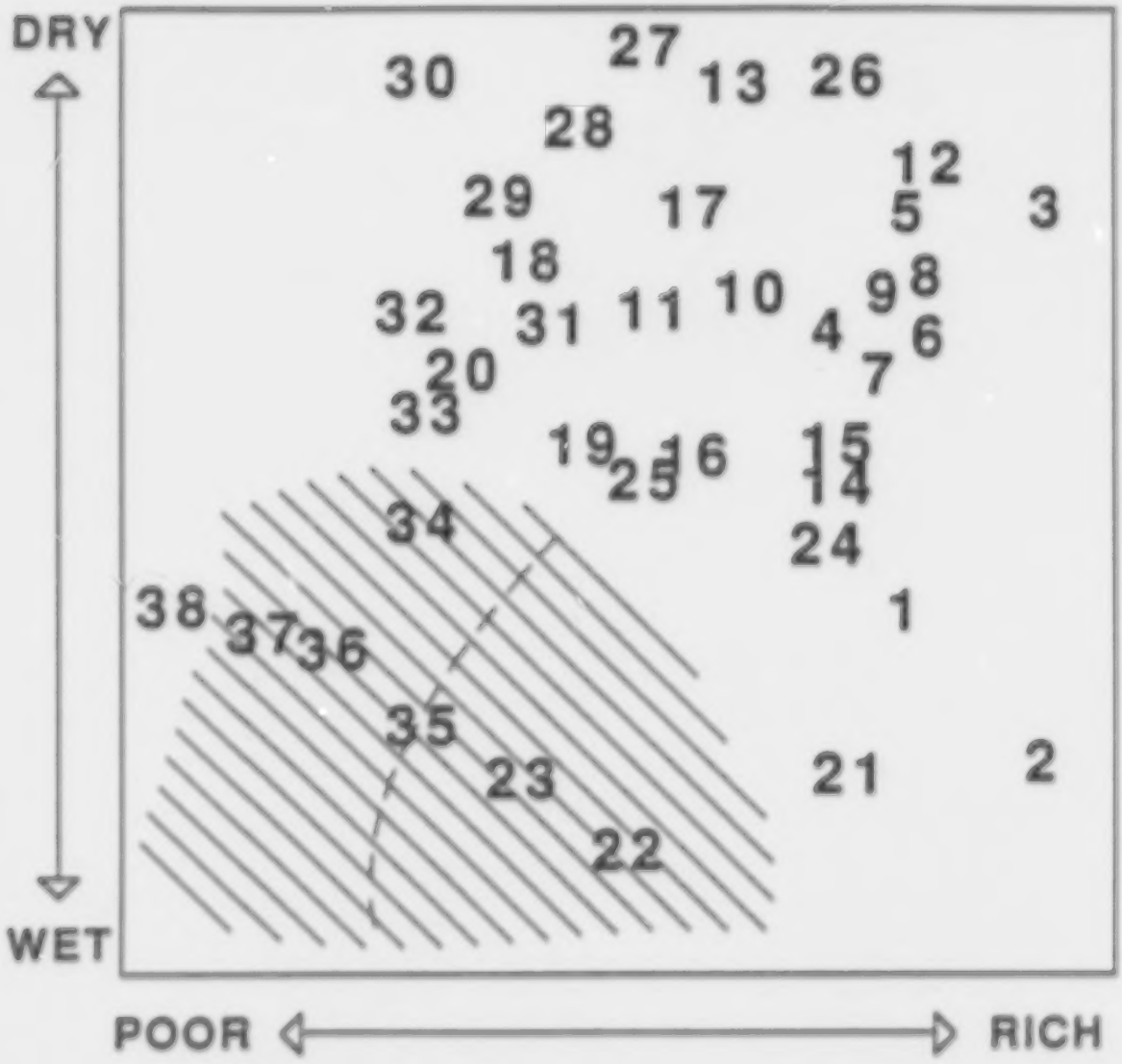

Figure 4. Treatment unit J includes the NWO FEC V-types that occur on primarily organic, sphagnum-dominated sites. V-types 22, 23, and 35 are nutrient rich and very competitive, and are part of phase J1; while phase J2 is less competitive.

3. Maximum benefits can only be achieved if you select the best crop tree regeneration method and crop tree spacing. You do this by analyzing site productivity through the utilization of yield tables that are responsive to the vast differences among the three phases of this treatment unit.

4. Usually one of the phases will dominate the mixed spruce-pine stands in your area. Do you know which one is the dominant phase in your management unit?

Essentially, the treatment unit is the level and scale that you should be setting your management objectives on.

This whole system begins to pay off when the NWO FEC information is combined with a digitized FRI on a geographic information system (GIS). This is where the NWO FEC and the treatment units help to actually develop a timber management plan and annual work schedules.

All eligible stands can be identified and allocated without treatment units; but treatment units are used to assign silvicultural treatment regimes to polygons and estimate the number of hectares which may:

1. require winter harvest;
2. require planting stock at certain densities;
3. require certain forest tending treatment;
4. require certain types of site preparation;
5. produce crops of specific yields at certain rotation ages.

Treatment units become the vehicle by which the NWO FEC is used in timber management. Good treatment unit definition will be used to optimize stand allocation and build ecologically sound prescriptions.

The advantages of treatment units are not limited to an organization committed to GIS, but they will benefit the most. Many of the industries in northwestern Ontario that have made a commitment to GIS will recognize that.

SUMMARY

We at the TDU are committed to the treatment unit concept and are currently using this concept to develop new technologies for use by forest managers. The flexibility associated with the construction of treatments means that anyone with a good comprehension of the NWO FEC has the knowledge and ability to customize the treatment units for his or her management unit and the specific forest or wildlife objectives set for it.

The Northwestern Ontario Forest Ecosystem Interpretations not only defines interpretations, but also has a "how to" section for developing treatment units. The TDU is also actively supporting field initiatives to develop new applications of the NWO FEC, with the intent of developing further applications.

Site-specific management, above all, requires an efficient, accurate and easily communicated method for describing sites and the Northwestern Ontario Forest Ecosystem Classification is that method.

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THE FOREST ECOSYSTEM CLASSIFICATION (FEC) PAYOFF IN TIMBER MANAGEMENT

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ABSTRACT

A proposal for utilizing Forest Ecosystem Classification (FEC) data in Timber Management Planning is presented. This data, collected prior to the harvesting of forest stands, can be put to use in a four step framework involving the pre-planning stage, the long term (20-year) planning horizon, the medium term (5-year) planning horizon and the short term (1-year) planning horizon. These stages, when properly tied together, can provide a concise database upon which a forester or technician can determine the best timber and other resource management options on a given forest area.

INTRODUCTION

Good morning ladies and gentlemen.

I am here today to speak to you about what we call the Forest Ecosystem Classification (FEC) Payoff in Timber Management Planning.

Chuck Mason and Dave DeYoe spoke this morning about the importance of Timber Management Planning and Silvicultural Planning. This is where the payoffs of FEC surveys can occur.

Payoff can be defined as a bribe. Unfortunately, with my present salary I won't be able to provide one to you this morning. Instead, my objective is to explain to you how the Thunder Bay District has used ideas provided by Richard Sims and Gerry Racey to develop a plan for the use of FEC data to improve and enhance planning and management.

At this point in time we have collected some good FEC data but we have as yet to put it to use. I am going to explain our proposal and subsequent uses for this data, and I hope that you will understand that we don't have all the answers. Either Al Barauskas or I would be more than happy to take your questions any time during the talk.

METHODOLOGY

Our first task was determining how to collect this FEC Pre-cut survey data, and then get out there in the "bushes" with our "ton" of equipment to do the actual cruising.

If any of you are interested in this logistical side of the operation, which I don't have time to cover, it is outlined in two reports, which will be available from me after this talk. That is the how side of things, but now I want to tell you why we collected this FEC data.

We have collected this data in order to provide some Payoffs in Timber Management Planning. The following is our "set up" for the Payoff, based on a framework of how we see FEC data fitting in

to the Timber Management Planning process currently under way on the Shebandowan Crown Management Unit.

The first part of the framework is the pre-planning stage: using the modified FEC cruising methodology, we cruised 3,941 hectares of forested land last fall in the Shebandowan Unit here in Thunder Bay District.

Our methodology at this point in the framework starts with actually incorporating the pre-cut survey methodology for FEC data collection.

The areas which can be allocated for harvesting in the operating plan period are surveyed by trained crews using the FEC Pre-cut survey.

The areas which were cruised in Shebandowan approximately constituted a five-year harvesting allocation for the unit. The areas to be cruised were determined based on the usual information, for example, access, silvicultural limitations, operability, oldest first, etc. As you are aware, this meant an enormous amount of valuable data was collected.

The next steps have yet to occur, but here is what we see as a plan:

Back at the office, FEC soils and vegetation types are mapped and more precise treatment units, which Gerry Racey spoke of, are developed. These are based upon the major factors affecting forest management decisions.

We can, as a result of this exercise, produce a new model of forest cover and site parameters, which will augment the FRI as the model upon which the operating plan can be based.

The second part of our framework involves the long term (20-year) planning horizon, or a Timber Management Plan. The rationale behind using the FEC information at this stage of the framework involves the benefits of site information, which are maximized when incorporated at an early stage of the planning process.

The FEC information will allow the development of the treatment unit maps. These maps will, in turn, allow the forester or technician to balance allocations from one five-year term to the next. It will also allow the forester or technician to more accurately allocate to the level of available resources, such as dollars or trees.

Our methodology at this stage involves the provision of some base tools. These include:

(a) Existing soils and landform data;

(b) Forest Resources Inventory (FRI) maps;

(c) Aerial photographs; and

(d) Accurate planimetric maps and most importantly, the FEC data collected during the pre-planning FEC Pre-cut surveys on the unit,

by utilising:

(i) Interpolated field data;

(ii) Photo interpretation; and

(iii) FEC/FRI correlation and additional field sampling.

We can, as a result, produce a complete map of moderate precision and high accuracy for the entire Shebandowan Unit. This map is what we refer to as a treatment unit map. It will provide an inventory model of soils, site and forest cover data and becomes the improved information base for the Timber Management Planning process. At this stage we are essentially augmenting the FRI with this additional amount of information.

The third part of our framework involves the medium term (five-year) planning horizon or the operating plan. The rationale at this stage is to create a "precise, fine-tuned" map or land base of the unit to be used in the next five-year planning period.

Our methodology here is to refine the original allocation resulting in the achievement of a balanced allocation by treatment unit.

Why would we want to allocate proportional to treatment unit representation? Some reasons might include:

1. an over-allocation of a treatment unit requiring winter-only harvesting operations might put your cutters out of work for a large portion of the year; or

2. an under-allocation of a treatment unit could provide extensive forest management/low cost regeneration opportunities or conversely, an over-allocation of a treatment unit requiring planting could mean that you might not have enough planting stock or approved targets to properly regenerate your allocations/depletions.

The ultimate goal in this exercise is to provide a framework for prime site and integrated resource management and balance the forest management program from one five-year period to the next.

The fourth and final part of the framework is with regard to the short term (one-year) planning horizon, or the annual work schedule.

The rationale for the FEC system at this juncture is to provide the ability to the forester or technician to evaluate management alternatives and then make the best choice, based on a detailed analysis of the benefits and costs of each alternative.

The methodology involves the forester or technician identifying the targets and objectives which are to be derived from the Shebandowan Unit, then determining which treatment unit or combination of units can be operated annually to best meet those targets and objectives.

These determinations can be made based on such factors as:

1) market demand for wood products produced on the unit;
2) funding for silvicultural programs; and
3) planting stock availability.

An example of how this methodology would work could be something like a projected shortfall from the local nursery for white spruce (Picea glauca (Moench) Voss) planting stock. Therefore, the forester or technician would select treatment units, identified in the Medium Term planning stage, which would be most suited for regeneration with other stock types or methods for the year of the projected shortfall.

As a result of this exercise, the forester or technician can determine site-specific allocations resulting in balanced annual combinations of:

- volume harvested;
- required silvicultural investments;
- units of future productivity; and
- recognition of Integrated Resource Management values within site-specific definitions of the treatment units.

Other Benefits of FEC Pre-cut Surveys

As you can see from the presentation thus far, the potential of the pre-cut FEC survey in Timber Management Planning is excellent. The "payoff" has hopefully become more evident to you.

We also see some other benefits of utilising FEC pre-cut surveys which can provide payoffs of their own. These include interpretations, which already exist in draft form, for FEC treatment units as they relate to or impact upon:

- harvesting considerations/methods;
- herbicide use;
- vegetative competition;
- stock type selection;
- operability considerations of the site;
- wildlife habitat; and
- spruce budworm susceptibility.

Another distinct benefit is the opportunity to get foresters and technicians conversing in a common scientific language based on the FEC, which provides a more meaningful description of a forest cover type, landform or forest ecosystem than terms such as "stag spruce" or "that dead balsam crap in Shebandowan." This common language also quantifies things that have been intuitively known about a forested land base through experience or trial and error.

Benefits also exist in the form of the training opportunities available to staff wishing to learn how to use the FEC system, thereby increasing their knowledge and their scientific or biological-based understanding of the forests present on their units.

Our technical transfer to the general public might also be aided through quantifying and simplifying the system which could be used to describe our forests to them on a "layman's level."

COSTS

The range in cost for an FEC pre-cut survey can run from $7.00 to $12.00 per hectare, depending upon whether OPC data is collected along with the FEC data and such factors as number or crews available to do the survey, ease of access, weather conditions, etc.

Production rates vary from an average of 106 hectares/day for road accessed stands to 297 hectares/day for helicopter accessible stands.

CONCLUSIONS

We have demonstrated, through a case-in-point presentation, where the potential lies for pre-cut FEC surveys in Timber Management Planning.

Current trends indicate that the Ontario Ministry of Natural Resources is moving towards greater amounts of reliable and useful data collection. At this time, we as resource managers must make a "pitch" to secure the required funding for data collection using systems such as the FEC Pre-cut Survey.

APPENDIX A

THE FEC PAYOFF IN TIMBER MANAGEMENT PLANNING

"Pssst... Wanna buy some data?"

Pre-Planning Stage

-- Funding secured for FEC pre-cut survey;

-- Survey carried out on areas allocated (five-year);

-- Allocation criteria, such as access, operability, etc.;

-- FEC treatment units developed and mapped without refinement; and

-- Treatment units augment existing information about the forest.

Long Term (20-year) Timber Management Plan

-- Produce a COMPLETE map that identifies treatment units (t.u.'s)

t.u. #1 INTESIVE SILVICULTURE

t.u. #2 EXTENSIVE SILVICULTURE

t.u. #3 NO SILVICULTURE

Long Term (20-year) Planning Horizon

METHODOLOGY:

1. The provision of base tools:
   -- existing soils and landform data
   -- forest resources inventory maps
   -- accurate planimetric maps
   -- aerial photographs, and
   -- cruise data;

2. By utilizing:
   -- interpolated field data
   -- photo interpretation
   -- FRI/FEC correlation, and
   -- additional field sampling.

RESULT:

The production of a complete map (of high precision and accuracy) for the treatment unit.

Medium Term (5-year) Planning Horizon

REFINED OPERATING PLAN AREAS

METHODOLOGY:

1. Refine the original five-year allocation to achieve a balanced allocation by t.u.; and

2. Extrapolate original t.u.'s to produce a more precise map.

RESULT:

Production of a new map (model) that will assist in the achievement of a balanced forest management program from one five-year period to the next.

Short Term (1-year) Planning Horizon

METHODOLOGY:

Determine which treatment unit or combination of t.u.'s best meet the annual targets and objectives.

RESULT:

Production of a site specific allocation map, resulting in the balanced annual combinations of:

-- volume harvested
-- units of future productivity
-- required silvicultural investment, and
-- recognition of I.R.M values within treatment units.

OTHER PAYOFFS...

FEC TREATMENT UNIT INTERPRETATIONS FOR:

-- Harvesting Considerations

-- Herbicide Use

-- Vegetative Competition

-- Stock-Type Selection

-- Operability Considerations

-- Wildlife Habitat; and

-- Budworm Susceptibility.

COMMON SCIENTIFIC LANGUAGE:

-- Provides a more meaningful description of forest-cover type, landform, ecosystem, etc.

-- Quantifies intuitively known *facts* about a forested landbase; and

-- Can be presented in "layman's terms" to members of the general public.

This = easier technology transfer.

COSTS AND PRODUCTION:

FEC Pre-cut Survey:

-- Cost $7.00/hectare; and

-- A two-person crew averaged 12 plots/field-day

FEC Pre-cut Survey (With OPC data):

-- Cost $11.24/hectare; and

-- Three two-person crews averaged 106 hectares/day (road accessed stands), and 297 hectares/day (helicopter accessed stands).

FEC
PRE-CUT
SURVEYS
PAY IN THE
END
NOTE
PLANNING
HORIZON

FOREST STAND DEVELOPMENT: CONCEPTS AND CONCERNS

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ABSTRACT

An understanding of forest stand development is a precursor to meaningful growth and yield estimation. As the demand for information on pre-rotation age stands increases, the need for models of stand development will intensify. This paper discusses some basic concepts of forest stand development and delineates potential strategies for modelling those biological processes.

INTRODUCTION

The Canadian forest industry is reaching a balance between calculated allowable cuts and mill demand, and increasing emphasis is being placed on the ability to accurately forecast the development of immature stands. This emphasis derives from the increased importance of stand increment to the calculation of sustainable harvesting rates. Conventional growth and yield estimates use available information from remeasured sample plots and stands of different ages to determine average development patterns of certain species groups and levels of site quality. Reliable data is scarce however, and growth and yield prediction relies on the law of averages; even if you predict the growth and development of every individual stand incorrectly, you can still be right, on average. In fact, for managed stand yield tables, we may not even be right, on average.

The eventual solution to stand level growth and yield estimation problems is the ability to describe the process of stand development. By knowing how individuals in a forest stand interact and grow, it should be possible to forecast potential yields and responses to silviculture treatments. Such forecasts can be based on information collected at an early age, potentially at the 'free-to-grow' point. This paper will review concepts of stand

development and propose growth and yield methodologies based on the ecological principles of intraspecific competition.

WHAT IS A FOREST STAND?

By definition, a forest stand is a population of trees of similar age and of uniform species composition. The point at which one stand changes to another, based on species group, physical barriers such as rivers, or silvicultural history or age, depends on an administrative definition in the forest region concerned. From the point of view of an ecologist this is very different from the concept of an ecosystem, which is an area homogeneous in all environmental conditions necessary for the development of a forest community; particularly soils, climate, and physiography (Green et al. 1984). But foresters are primarily concerned with the development of harvestable timber and, as such, look at stands with respect to future harvest patterns. Thus, a given stand may cover more than one site type and more than one stand may be found on a given site type.

Growth and yield prediction assumes that a stand is homogeneous with respect to site quality, age, and species composition. This is unrealistic in practice and all these attributes vary to some degree within a stand. Thus, unless a forest is described at the individual tree level, it is necessary to accept variation within the concept of a stand.

PHASES OF STAND DEVELOPMENT

Forest stands originate from a disturbance. In Canada's boreal regions that disturbance is usually through major forest fires; although on wet sites or at high elevations the disturbance can be minor, such as individual tree fall. In addition, human intervention in the forest has created a widespread, new type of disturbance: forest harvesting.

The regeneration phase of stand development determines the density and species composition of the future stand. In nature, species such as jack pine (Pinus banksiana Lamb.) or trembling

aspen (Populus tremuloides Michx.) have adapted to regeneration after disturbance by holding a continuous seed bank in serotinous cones, or by having the ability to sucker or sprout rapidly. Silviculturalists influence the regeneration phase by carrying out treatment, such as site preparation or planting, that will produce regeneration of the desired species and density. During the regeneration phase, tree species must cope with competing vegetation and various features of the site that influence the availability of light, moisture, and nutrients. The ability of species to cope with environmental conditions will determine the mix of species in the future stand.

After the free-growing point, where stand density and composition are set, there tends to be a period of rapid growth; individual trees have high levels of light, moisture, and nutrients available to them, and therefore, a high positive physiological balance. The physiological balance of a small tree is highly positive because foliage (the photosynthesizing tissue) comprises a high proportion of the total plant biomass and the wood, roots, and twigs (respiring tissue) comprise a lower proportion than they will as the tree ages.

As individual trees grow, they begin to interact with one another and the physiological balance between the anabolic (constructive metabolism) and catabolic (destructive metabolism) processes decreases (Tait 1988). This is the phase of crown closure and resource competition in the stand. As this phase continues, the stand begins to reduce in density due to self-thinning mortality; and individual tree growth declines further.

Finally, after a period of time, the stand will begin to break up due to physiological aging, discontinuities in nutrient cycling, and the increasing susceptibility of trees to insects and disease (Waring 1987). During this last phase, the stand is usually either cycled by fire, harvested, or naturally regenerated to shade-tolerant species. These phases of stand development are universal and they drive the dynamics of stand structure.

WHAT IS STAND STRUCTURE?

The 'structure' of a stand, or population of trees, relates to the density of individual trees, the percentage composition of species, their ages, and their sizes. Stand structure is important to foresters because it defines the number and size of individual logs that can be extracted from a given area. Stand structure is described using a series of attributes such as a forest cover type, the frequency distribution of individual tree sizes, and measures of stand density (Figure 1).

Stand structure will vary greatly between stands that originate naturally or via planting, among stands of different natural origin, and among stands of different species. These differences originate with the density and distribution of trees in the regeneration phase, the process of intraspecific competition, and the ratteand pattern of mortality. In natural systems, damaging agents, such as snow, ice, wind, insects, and diseases, also account for differences in stand structure.

WHAT CONTROLS THE DEVELOPMENT OF STAND STRUCTURE?

Much has been written in the ecological literature about factors that affect population structure. Primarily, they are: (i) the variation in size and genetic make-up of individuals at the early pre-competitive stage; (ii) the variation in quality of microsites; and (iii) the process of intraspecific and/or interspecific competition (Harper 1977). Even without competition, as when individual trees are very widely spaced, stand structure changes over time. There is a broadening of the size distribution as slower and faster growing trees sort themselves out, and a change in the shape of the size distribution from a normal distribution to a more skewed distribution.

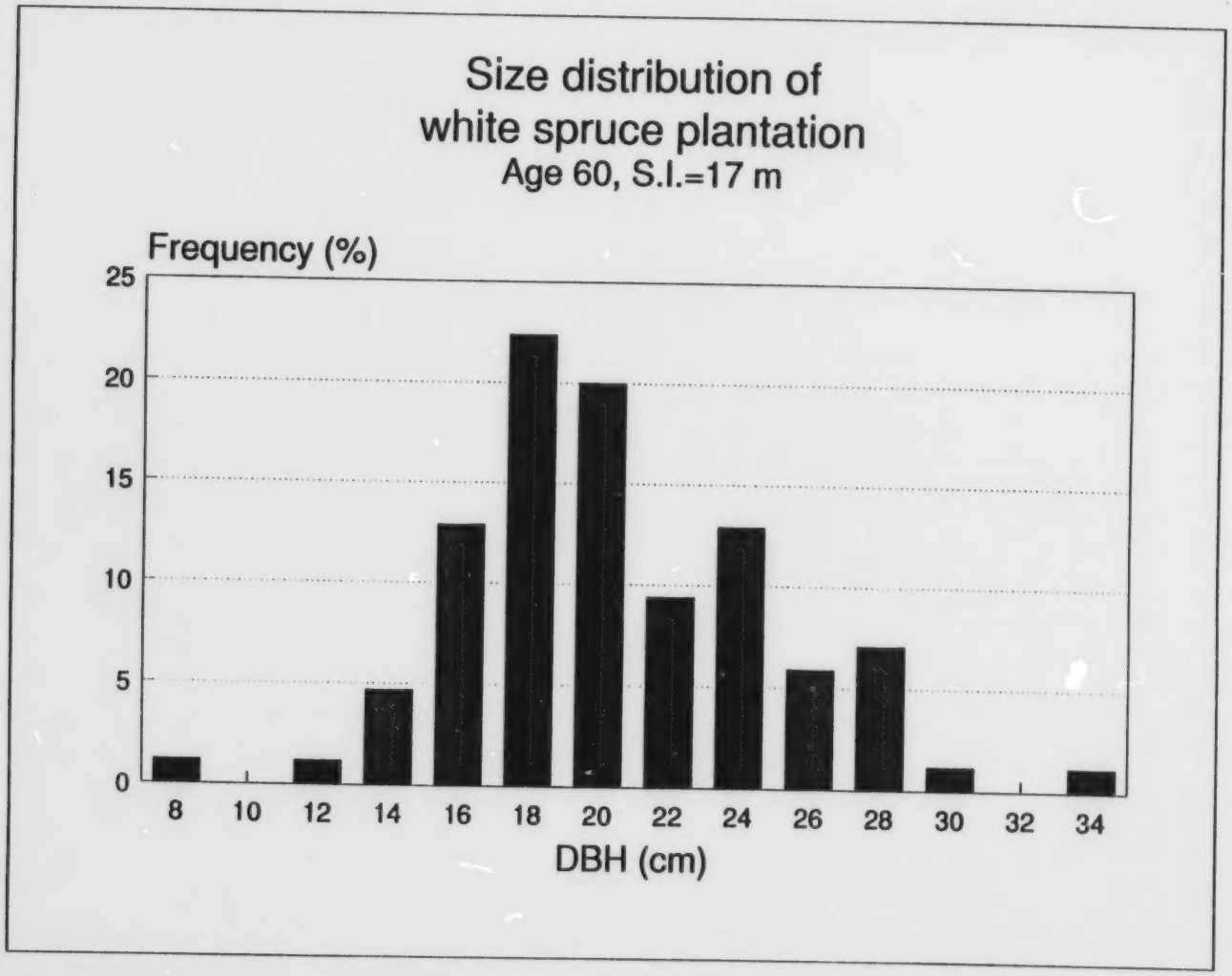

Figure 1. Size distribution of plantation-grown white spruce. The size distribution is a useful measure of stand structure.

As the stand ages, however, and trees grow to a point where they interact with one another and must share the available light, moisture, and nutrients of a site, competition becomes the factor of overriding importance. Within-population plant competition has also received considerable scientific study. Recent work has centred on describing how individuals share resources such as light. The intuitive notion is that as smaller plants are out-competed by larger plants for resources, their growth slows and eventually they die. Ecologists describe this in terms of the asymmetry of resource sharing, relative to the stature of an individual in the population. This term was used by Brand and Magnussen (1988) to describe the process of competition in red pine (Pinus resinosa Ait.) stands. In effect, a coefficient of asymmetry has now been developed for red pine plantations, at the Petawawa National Forestry Institute, which allows prediction of how the growth rate of individual trees of different sizes in the stand changes as stand density increases (Magnussen and Brand 1989). This type of model allows prediction of the change in stand structure of red pine plantations over time.

FOREST PRODUCTIVITY

A primary concern in forest management is the rate at which a stand will develop to merchantable size. This rate is controlled by the productivity of site conditions for the species that make up the stand. While thinning or plantation spacing can accelerate the development of individual trees by minimizing the intensity of competition, it is still necessary to recognize the site features that control the inherent productivity for tree growth.

Forest productivity arises from the rate and balance between the supply of light, moisture, and nutrients in an ecosystem. The most effective way to gauge forest productivity is through the height growth of the tree species. Height growth tends to be largely independent of competition intensity and is expressed fairly early in stand development. For example, Thrower (1987) indicated that using three or more height increments from trees

greater than 2.0 m in height could explain between 83% and 89% of the variation in site index for white spruce (Picea glauca (Moench) Voss) plantations. The success of this study and others indicates that forest productivity can be estimated for stands at the free-growing point.

DENSITY, DISTRIBUTION, AND STOCKING

The process of competition arises because the density of the stand causes interactions among the individual trees. Small trees can be more closely spaced without being affected by competition than can larger trees. This fact is well recognized; foresters generally use thinning to reduce stand density, thereby reducing the intensity of competition for resources by the remaining trees. Yet, there appears to be uncertainty about how many trees suffice at an early age to lead to a particular stand structure at a reasonable rotation age.

Stand density is the total number of tree stems per unit area. Density can be very patchy and does not necessarily give a good indication of the degree to which regeneration will fill the area with mature trees. This has led to usage of the term stocking, defined as the number of well-distributed trees relative to some arbitrarily defined optimum reference stocking. Minimum stocking is meant to represent a condition that barely leads to a stand that utilizes the potential of the site for timber production.

The determination of this optimum and minimum density seems to have had very little scientific basis in the past. Only in the last decade have tools been developed, based on ecological principles, that lead to an understanding of the development of stand structure. One of the most useful tools has been the "Density Management Diagram" of Drew and Flewelling (1979). Based on the -3/2 power rule of self-thinning, the diagram indicates the average tree size that a stand can attain, for any given density (stems/ha). Using this diagram for managing coastal Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco), it is possible to set an average stem size objective and determine planting density and

point of intermediate thinnings. It is also possible to obtain average tree height, diameter, and stem volume at time of final harvest.

These density management diagrams show the relationship between stand density and yield, but do not allow estimation of the time it takes for trees to grow to different sizes. Smith and Brand (1987) produced a stand density management diagram for red pine (Figure 2) and linked this with site index equations to produce a growth and yield model based on the -3/2 power rule. While the -3/2 power rule has come under criticism by some researchers as being variable between species, statistically inestimable, and only functional for a certain range of densities (Weller 1987, Zeide 1987), it still retains many benefits in describing stand development for individual species, particularly in plantation monocultures.

SUMMARY: STAND DEVELOPMENT AND GROWTH AND YIELD

From a biological perspective growth and yield estimation is concerned with describing the dynamics of a population of trees on a site, including the rate of growth, the evolution of stand structure, and the potential characteristics of the stand at some future point in time. While all the biological processes of stand development are not completely understood and vary dramatically from site to site, several useful quantitative tools are now available. These tools, including the stand density management diagram, the early estimation of site index, and the prediction of stand structure through coefficients of asymmetry in the competition process, could lead to site-specific, biologically-based growth and yield estimation. More work is needed, however, in the development and testing of these models so as to bring them to practising forester.

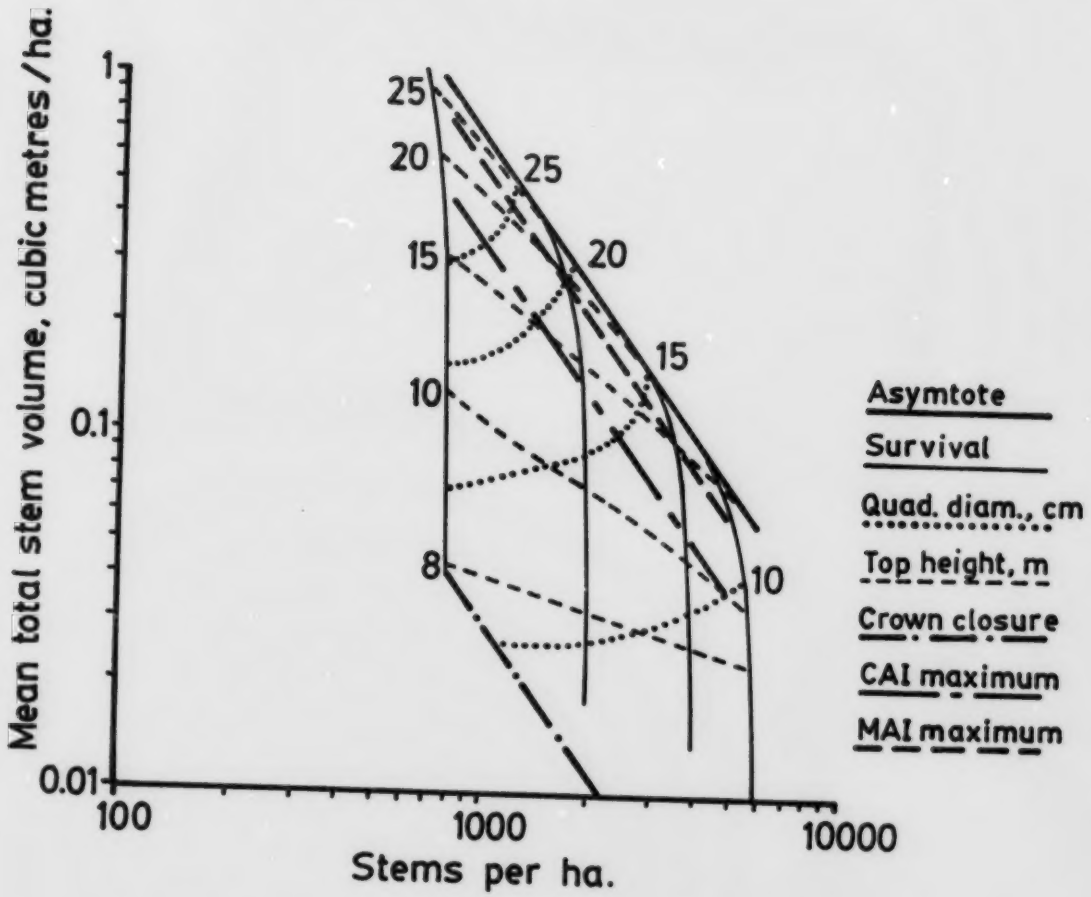

Figure 2. Stand density management diagram for red pine. Diagram indicates the relationship between maximum average tree size and stand density in stems/ha. Isolines for average height and diameter can also be read from the graph (redrawn from Smith and Brand 1987).

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INTEGRATING SITE-SPECIFIC TOOLS

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ABSTRACT

It would appear that there are going to be strategic timber supply problems in northern Ontario in the future; foreseen by our best forest-level modelling efforts. These problems will likely be exacerbated through both the lack of timely application of the necessary absolute level of resources and the failure to more effectively deploy currently existing resources on the ground and in the forest to improve site-specific forest management. Site-specific tools which efficiently integrate a variety of planning factors, such as the pre-cut silviculture prescription, are seen as some of the best means that are currently available and within the power of most forestry organizations, to most forestry organizations, to improve the situation.

INTRODUCTION

Good afternoon ladies and gentlemen, fellow colleagues.

I believe that by this time after lunch, the human body is physiologically almost asleep... and by the end of this talk, many of you might be glad of it.

I must apologize for the fact that I will not be speaking on the Spruce Falls dataset as indicated on the agenda. It is presently undergoing protracted editing and is proving singularly uncooperative in not conforming to the expected curvilinear model; so, for the moment it's a bit embarrassing and we have some problems to work out. Perhaps by this time next year, we'll be able to report on it in full. Instead, I'm going to talk on 'Integrating Site-Specific Tools To Help Solve Our Strategic Problem.' That's the official long title. The unofficial title

is 'Let's Do Our Bit To Make Sure The Emperor Has Some Clothes,' the emperor being the quality of our site-specific management.

As an Ontario-trained forester who went away and worked in B.C. for nine years, picked up a few incendiary ideas about silvicultural practice and then came back, I feel a little like the IRA terrorist who, having blown himself up with his own bomb, arrives at the pearly gates armed to the teeth; whereupon St. Peter tells him, "You can't come in here dressed with all those grenades hanging off your shirt," and the guy replies, "I don't want to come in Peter, I'm giving you two minutes to get out!" (This is what happens when an operational silviculturist goes bad and joins a TDU.) I'm also reminded of Winston Churchill's account of his floor-crossing from the Conservative Party to the opposition and then back again: "It's one thing to rat, but it takes real nerve to re-rat." (a paraphrase) I guess all that this analogy really demonstrates is that your friendly Northwest TDU coordinator is a bigger rat than I am.

I'm going to tell you what I'll say; I'll say it; then I'll tell you what I've said. This is because I'm convinced of the adage that every time someone gets up to speak, there are invariably four speeches, not just one. They are: the speech that the speaker thinks he gave, the speech he actually gave, the speech the audience thinks it heard, and finally, the one that's reported in the papers the next day.

I'm simply going to give you a general overview of the strategic forest management problem with regard to site-specific tools in our region as I see it; discuss this problem in terms of the first generation of site-specific tools we now have available; discuss other tools we want to bring to bear on the problem in the future; and finish with some of the constraints and opportunities inherent in the whole process of trying to help solve the problem.

DISCUSSION

The Problem

The Northern Region basically represents 1/3 of all Ontario in terms of forestry: 1/3 of the cut, 1/3 of the budget, and 1/3 of the headaches and opportunities. We have a standing growing stock worth $18.5 billion before any value is added, if it were all cut down today as roundwood at the millgate. We cut 60,000 hectares a year and reforest 40,000. That means we are adding to the NSR backlog every year and we have a timber supply shortfall estimated to arrive in 50 years; in some localities, even sooner. After spectacular growth, up almost to the maintenance of basic forestry level, forestry budgets are decreasing, not the other way around. And so, there is virtually zero opportunity for doing a lot of intensive, high-yield silviculture, as long as we're not even being funded to reforest what we cut.

We have 8.4 million hectares of Crown Production Forest Land and only about one forester for every 120,000 hectares. And those that we do have, we load down with so much paperwork, reports, timber management planning and E.A. involvement, that it's difficult for them to get to really know their land the way they want to or use the site-specific tools that are available in a systematic fashion. Moreover, we provide every incentive for foresters to leave the field, and few incentives for them to stay there.

These are internally correctable problems, but ones which require changes in organizational structure, leadership philosophy and policy. In the Black Forest, there's a forester for every 10,000 hectares - that's twelve times the intensity of professional stewardship, without much more ecological diversity. So it's plain what we're up against, this situation pervades across Canada, and it's nothing new. But it remains the background against which we must humbly consider using the term 'site-specific,' lest we fool ourselves into thinking we're doing better than we are actually doing; or worse, in fooling ourselves, be **perceived** as attempting to hoodwink the forest's owners, the public.

I, like many of you, have made $50,000 silviculture decisions inside of 30 seconds, while hovering above a site in a helicopter; that is as close to the site as you sometimes get, and it's no fun because you can't really do a good job under those conditions and everyone knows it, or ought to. In Dean Baskerville's words, we as foresters are not yet, "in the forest," and right now the emperor probably only has on a pair of boxer shorts. He's not exactly obscene, but he's hardly presentable to the public.

That's the strategic problem as I see it; that we do not yet have the money, manpower, or appropriately structured organizations to properly implement, "in the forest," the site-specific tools which are crucial in order for us to achieve our district, unit and FMA-level objectives. These objectives must not be merely qualitative, but quantitative in terms of species mix, volume, timing and quality of desired end product and dollar value. Do these tools even exist? Yes and no; some do and some don't, and some need work, for example, the Spruce Falls dataset.

Existing Site-Specific Tools

The tools which have been developed historically to lay a foundation for site-specific management in Northern Region are threefold.

The first is the **Prime Land Soils Key** and companion detailed soil surveys at 1:15,840 or 1:20,000 scale. The key permits a forester or technician to classify a site into one of eleven soil subclasses, each of which contains inherent assumptions about limiting features to timber productivity. We have, however, been told by some of our field foresters that the key's usefulness in the field is limited because it's too simple; that is, finer detail is required in the key to enable more adequate site-specific descriptions. There are also more than 40,000 hectares, nearly 5% of the total Production Forest, in Timber Management Plans which have detailed soil surveys mapped; information which we've also been told would be useful for site-specific, stand-level prescriptions. This intensive soil survey program is continuing

in spite of COFRDA's demise, mainly because our companies are pumping in their own money for it.

The second tool is the **Forest Ecosystem Classification (FEC)** for the northern half of the region, the Clay Belt. It is a classification framework and mapping system based on soils and vegetation from 250 ten-by-ten metre plots, which allows a systematic ecological characterization of Clay Belt sites into 13 Operational Groups. It has been found that there is a wide range of timber productivity, as indicated by site index, even within each Operational Group. And so, while extremely useful for determining site-specific harvesting and regeneration options, the classification, never designed to interpret productivity in the first place, is weaker in its ability to help predict timber yields; an essential consideration in any prescription.

The third tool, or set of tools, I mention with trepidation. These are recently produced **net merchantable yield curves by site class** for black spruce (Picea mariana (Mill.) B.S.P.), jack pine (Pinus banksiana Lamb.), mixed-wood stands and untreated cutovers. I say trepidation because they are very quick and dirty estimates based on Plonski and Smith's work (modified industrial experience of the amount of merchantable wood they are usually able to remove from a site) and still without the benefit of any rigorous, statistically valid corroboration, even from Northern Region's other data sets. But, the curves are first approximations that are currently being applied at the forest level (e.g., in NORMAN, our regional wood supply model; in Abitibi-Price's modelling case study; and in the Ministry of Northern Development and Mines' agroforestry initiative) and could be used for site-specific yield prediction in silviculture prescriptions until we get ourselves something better. (The next approximations will probably be influenced by empirical information on plantation and unmanaged yields from Quebec by Boudoux (1978) and Bolghari and Bertrand (1984). So, although we have not advertised them, people seem to be using them.

At the moment then, we are essentially limited to these three site-specific tools: the soils key and detailed soils maps, the Clay Belt FEC, and the initial net merchantable yield curves. Theoretically, at least, there should be no excuse why any field forester cannot site-specifically classify each block of ground he's working on using either the soils key or the FEC. What have we got planned to improve the situation?

Future Site-Specific Tools

First, we intend to both refine and expand the FEC to the southern half of the region, so that we will have one integrated classification for the whole region. It must be simple to follow and useful at both the forest and stand level. It will incorporate within itself the Prime Land detailed soils information, vegetation and any independent effects of climate. We want it mappable through remote sensing, able to be loaded onto a GIS and we want a field guide to pre-cut and, hopefully, post-cut prescription-making on-site. It should include short silvicultural, engineering, and wildlife interpretations, without being a cookbook. It should also include succession information to allow prediction of when we'll have weed problems on-site, and should include as many good site-specific yield curves, value and yield tables and species-specific density management diagrams as we can muster; to allow the field forester the full range of treatment options and to be creative in formulating spending and yield trade-offs in response to the site's specific set of circumstances.

Second, through what's known as the **Plonski Project**, we are beginning to develop what I'll call a 'Star Wars' arsenal of site-specific and forest-level tools. These are computerized decision support systems, otherwise known as 'expert' systems, which involve the integration of multi-sensor imagery (from satellites, airphotos, and radar), GIS and wood supply simulation. This will eventually allow a field forester to "see" a site through the eye of the computer monitor, to tell the difference between a pine and a spruce, to determine the stand's density (radar's contribution)

and even check on an individual tree's internal biochemistry, for example, the lignin to cellulose ratio. He will then proceed and get answers to questions like, "What happens to my allowable cut if I plant this site next year or leave it alone to plant another richer site, 50 miles further from the mill, without access?" (I can't bring myself to use that term 'Maximum Allowable Depletion' in public.)

Now, unless forestry technology leapfrogs from what we ever imagined was possible, as it appears to have done recently in physics with room-temperature fusion, I cannot see the day when a forester can adequately do his or her job totally from behind a desk, with a computer. No matter how sophisticated our GIS and expert systems get, or how much information we can feed into them about a site, they can never answer all our site-specific questions; nor should they ever be allowed to usurp the forester "in the forest" making the site-specific, artistic, and business decisions based on the best science available. Forestry is too complex and dynamic for that. They are great tools to help us make site-specific decisions; they do not decide for us.

What then is the mechanism for this site-specific decision? The ultimate third tool? It is the site-specific, pre-cut silviculture prescription itself, which integrates the biological, biometric, economic and administrative elements of the previously mentioned tools at the site level. It has four basic functions, providing:

1. A logical framework for **analysis** of proposed treatments and environmental impacts;
2. **Direction** for carrying out the treatments;
3. Documented **justification** for the treatments; and
4. A **record** for later evaluation of the treatments.

It also has four components:

1. An ecologically classified **site and stand description;**

2. A **ranked management objective(s)** in terms of product, species, volume, size, class distribution, mean diameter, branchiness and stem quality. The management objective might not be for timber, or the timber objective might rank below other management objectives such as quantified wildlife habit;

3. A **silviculture system**, identified with a rationale and a **schedule of treatments**, with ranked alternative scenarios, should conditions warrant; and

4. A **professional endorsement**, or in other words, a signature of a forester accepting real accountability for its content.

The basic concept of a site-specific prescription must, I think, be very old and may have been taken over by forestry from agriculture. At any rate, I learned it first at university from a former Ontario Provincial Silviculturist. But I'm afraid it has many detractors who charge that it is too expensive; a redundant planning exercise and paper nightmare; prone to imprecise predictions about fuel loading, for example; and even that it is an unwarranted intrusion into an already acceptably-planned state of affairs, which dictates that it is not necessary to see a site before it is logged. To all these charges, we plead 'not guilty' on the prescription's behalf. Because what is acceptable planning in forestry? Surely it is planning that lays out a simple, quantified, flexible, feasible, ecologically appropriate course of action beforehand; that is linked to upper-level objectives; that has easily measurable outputs which, in turn, are linked to lower-level objectives and expenditures; that is easily audited; and that has the broad, enthusiastic support of the people who have to use it. I do not see the current planning system possessing these characteristics.

We need the pre-cut prescription because:

1) It is the missing link that ties the TMP Ground Rules to what actually happens on the ground, thus enabling us to achieve forest-level objectives;

2) Objectives outlined for the management unit as a whole may not be applicable, for ecological, technical or economic reasons, to a specific stand. An example from the Smooth Rock Falls Unit before it changed was when, as a result of traditional thin-tired skidder logging, more than 40% of the total clearcut area was rendered untreatable and unregeneratable because of lowland site damage; and

3) Pre-cut prescriptions tend to preserve treatment options. It is the only tool which efficiently integrates all other site-specific tools, i.e., the cruise, the FEC, yield information, habitat and on-site silvicultural knowledge, economics, a defined area and defined managers. It then becomes useful both in ensuring professional accountability and as an adaptive learning tool, since there is a benchmark decision.

Now, in advocating the adoption of this site-specific tool, we should not be unaware of the problems of its implementation; but we need to at least begin the debate. There are several problems; some have already been touched on. There are legal, organizational and professional constraints to implementing pre-cut prescriptions in Ontario. Legally, there is no statute requiring it, nor for a forester to have to sign it, nor is it in the FMA contract. Organizationally, we have to integrate it into the TMP process and there are personnel structure and union considerations. Professionally, there are few managed stand yield tables and even if we had them, according to the U.S. Forest Service's Robert Curtis, we would only be right in our yield projections plus or minus 15%, half of the time. But we have to start somewhere and there will always be uncertainty in forestry. That's why it's an art.

We have to remember that when we presume to manage public land, and whether or not there's a law that says we have to do something, we enter into an ethical contract with the owner, the people of the province, and we are going to be judged on how well we are fulfilling its terms. Pre-cut prescriptions are like oatmeal. Having it all the time is sometimes dull but it prevents heart attacks later and there's just no substitute for the real thing. We might even get told to eat our oatmeal whether we like

it or not. That is precisely what the owner did in B.C. last year by making the pre-harvest prescription law; but they went overboard. It's too bureaucratic. The foresters have to advertise all site prescriptions in the paper and hold public dialogue two months before a wheel can turn.

Let's get out in front of the situation here and take advantage of our rare opportunity to implement this tool the way we want, before we're told to do it the way we don't want. This is a great opportunity for us to demonstrate that we really are concerned about all the province's forests, not just the 1% that we call 'Areas of Concern.' This term simply begs the question: "Is the rest of the forest of concern to you guys?"

CONCLUSION

I've told you what I was going to say, I've said it, and now I'll tell you what I've said.

We have to recognize some of the contributing elements to our strategic problem, and there are at least three: reduced budgets; inadequate manpower; and incorrectly deployed manpower. This leads to the inability to do site-specific management through rigorous, systematic and integrated use of site-specific tools. The first two elements we can't do too much about, although even this is debatable. But the third, we can. And it therefore may be the most important in terms of our ultimate standing before the public owner.

I went over the tools that we presently have and talked about tools that we need to bring on-stream quickly with a special emphasis on the integrator tool, the pre-cut prescription. I've gone over some of the constraints to its implementation and mentioned that we here in Ontario have a real opportunity to get the public onside with some proactive changes.

By this time next year, it would be good if we could say we've done our job; clothed the emperor as much as we possibly could and at least got him a pair of pants, even if his legislature lets him go shirtless.

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TOOLS FOR CONTROLLING VEGETATION: A MINNESOTA SCENARIO

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ABSTRACT

The Forest Vegetation Management Cooperative is a program in the University of Minnesota's College of Natural Resources that addresses forest vegetation management problems. The cooperative conducts applied research and transfers research results and other information back to the vegetation manager. There are currently four research projects being addressed by the cooperative.

The Forest Vegetation Management Cooperative: the University of Minnesota's approach to solving forest vegetation management problems.

BACKGROUND

The Forest Vegetation Management Cooperative is a program offered at the University of Minnesota's College of Natural Resources, whose mission is to further the science and practice of forest vegetation management through cooperative research, and to inform natural resource managers about safe and effective forest vegetation management practices. The cooperative began in 1984 as the Forest Weed Control Program, receiving large research grants from the Blandin Foundation in Grand Rapids, MN; the Minnesota Department of Natural Resources; and the University of Minnesota's Agricultural Experiment Station. While many of the forest management agencies responsible for starting the Forest Weed Control Program were located in Minnesota, it soon became apparent that the forest weed control problems that we faced were present all over the Lake States Region. Thus, in 1986, the name was changed to the Forest Vegetation Management Cooperative to reflect the idea of a large group of forest management agencies, from a

wide geographic area, working together and sharing the cost of solving forest vegetation management problems.

The Forest Vegetation Management Cooperative is housed at the Cloquet Forestry Center, the College of Natural Resources' forest experiment station located near Cloquet, Minnesota. The benefits of working out of the Cloquet Forestry Center include the availability of the surrounding 1,400 contiguous hectares of forest land to conduct research trials on, as well as accessibility to many possible research sites on forest lands belonging to other forest management agencies in northern Minnesota.

The Forest Vegetation Management Cooperative is similar to the Auburn University Silvicultural Herbicide Cooperative at Auburn University in Alabama and the Coordinated Research on Alternative Forestry Treatments and Systems program at Oregon State University. Both programs have been in existence longer than the University of Minnesota Cooperative and have greater financial resources to work with.

The work of the Forest Vegetation Management Cooperative is guided by an Advisory Committee and carried out by the Forest Vegetation Management Specialist. The Advisory Committee is made up of representatives of vegetation management organizations who are due-paying members of the cooperative. In addition to membership fees, other sources of financial support currently include continued funding by the University of Minnesota Agricultural Experiment Station and the Minnesota Department of Natural Resources; monetary assistance from small grants to carry out contract research; and funding from the Minnesota Extension Service, to assist with teaching and education programs for forest vegetation management.

FOREST VEGETATION MANAGEMENT PRINCIPLES

A good forest vegetation management program starts with a basic understanding of why it is important to control forest weeds. Forest weeds compete with crop trees for the limited resources available on a site that are needed for plant growth. These

resources include sunlight, water, nutrients, and growing space. If the competing vegetation uses the majority of these resources, there is little left for the crop trees. By controlling (not necessarily eliminating) the competing vegetation during the early years of the plantation, more of the necessary resources are channelled to crop trees, which will get the seedlings off to a healthier, more vigorous start.

The two main objectives for managing competing vegetation are to increase crop tree survival and growth during the establishment phase of the plantation's life. Increasing survival and growth protects the landowner's monetary investment in the site and allows that site to grow more wood in a shorter period of time. Other weed control objectives may be important also. One may be the elimination of a particular noxious weed as required by state or county laws. Another may be to control a particular weed that is the home of a tree damaging insect, as in the case of the Saratoga spittlebug (Aphrophora saratogensis) in red pine (Pinus resinosa Ait.) plantations. Removing the host site of sweet fern (Comptonia peregrina (L.) Coult.) also forces the insect to leave the area, thus reducing seedling damage.

Weeds rapidly invade sites where some sort of disturbance such as harvesting, site preparation, or natural fire has occurred. Because forest vegetation management is a young discipline, many of the weed control principles used in forest management were taken from agricultural weed control principles. While many of the competition principles are similar between the two disciplines, there are some very important differences. Controlling weeds on forested sites often involves more complex vegetation and larger weeds than on agricultural sites. The establishment period for agricultural crops is generally a few weeks in the spring, whereas forest crops can be up to 10 years. In both disciplines, it is important to implement weed control measures rapidly, before allowing the weeds to overtake the entire site and make crop establishment more difficult.

Most forest managers have not had any formal training in weed science. They often rely on intuition as the means of determining whether or not to manage vegetation because good quantitative decision-making methods are not available. Foresters often view a young plantation as having competition from woody brush and competition from herbaceous weeds and grasses without really knowing which type of vegetation is the most detrimental. It is important to identify the major weeds present on a planted site and to know which weed control measures are appropriate. It is also very important to have well-defined management objectives for a plantation. If the sole objective is to maximize wood fibre production, then intensive vegetation management methods are necessary. However, if there are multiple use management objectives, such as wood fibre production and wildlife management, then less intensive vegetation management methods are acceptable.

RESEARCH ACTIVITIES

The Advisory Committee has identified four main research projects. Several field studies are included in each research project. Currently all of the studies in projects 1 and 2 test herbicides. The Forest Vegetation Management Cooperative does, however, review the results of non-herbicide vegetation management trials conducted by other research organizations. Several of the current studies are experimentally designed trials that collect very detailed information. Other studies are operational (non-replicated) demonstrations that are conducted with far less detail. The cooperative has established more than 30 studies since 1984, 19 of which are currently under way.

Project 1: Investigate site preparation methods and develop guidelines for use.

Site preparation is carried out after harvest, but prior to planting, to make the site more amenable for planting by removing debris left after logging and to control undesirable vegetation. The three most common methods of site preparation are heavy equipment, prescribed burning and herbicides. Quite often a combination of the three methods is necessary. The site preparation method or combination of methods used depends on many factors, including: previous cover type, harvesting method used, species to be planted, and planting method as well as the topography and inherent productivity of the site.

There are several types of heavy equipment used for site preparation. One of the most common is a crawler tractor or skidder with a rake attachment on the front. This equipment allows for moving the logging debris into windrows or piles without moving the topsoil off the site. Sometimes crawler tractors are used with clearing blades which shear and pile undesirable vegetation left standing on the site following harvest. While heavy equipment does a good job of cleaning up the site, it does not provide adequate control of competing vegetation. In addition, improper use could remove too much top soil which could lead to reduced productivity in the future, in spite of what appears to be excellent weed control (weeds do not invade rapidly when the surface consists of sterile soils that were originally below the top soil).

Prescribed burning can also be used to reduce harvesting debris on the site. However, the use of broadcast burning for site preparation is seldom practised in Minnesota because climactic conditions are rarely suitable to allow a good burn without the risk of causing an uncontrolled fire. Fire is commonly used in combination with mechanical methods to burn the windrows or piles of debris left after raking. Vegetation control resulting from fire varies greatly, depending on the type of vegetation and the intensity of the fire.

Herbicides are also commonly used to prepare sites for planting. This site preparation method does not modify the physical barriers to planting, but it does an excellent job of controlling potential competition. Using herbicides prior to planting is easier than after planting. The risk of herbicide damage to crop trees is greatly reduced since the crop trees are not yet planted when the application is made. Newly planted seedlings are able to take advantage of their relatively free-to-grow conditions during the first couple of growing seasons. There are currently seven trials in Project 1, all of which test herbicides for site preparation.

Project 2: Investigate release methods and develop guidelines for use.

Release refers to controlling the competing vegetation around crop trees, thereby "releasing" those trees from the competitive effects of other plants. A release treatment is often not necessary if there was adequate site preparation. When release treatments are needed, they are usually implemented sometime during the first five years of the plantation's life.

Several methods of release are available. They include: mulching, grazing, hand-cutting, and spraying with herbicides. All of these methods will yield some control over weeds, with some methods giving longer control than others. It is up to forest managers to choose the method that best fits their particular situation.

There are several mulching materials that can be used as a forest release treatment. Natural mulches are made up of ground plant materials. Synthetic materials are being tested along with paper or cardboard mulches. Black plastic is not very good because it prevents moisture from getting into the soil. Mulching around crop trees should reduce weed competition and increase soil moisture. The effectiveness of mulching in preventing weeds is variable, and this method is probably not feasible for large-scale regeneration projects.

Livestock grazing has been tried as a method of releasing crop trees (both hardwoods and conifers). Livestock have been shown to eat a wide variety of shrubs and herbs without adversely affecting crop trees, if the number of livestock and periods of grazing are carefully monitored. Sites to be grazed usually need to be equipped with electric fencing.

Hand-cutting of woody competition has been used on occasion, but the results of this method are often not acceptable due to rapid resprouting of woody brush. The equipment used ranges from non-motorized hand-cutters to brush saws and small chains. Hand-cutting is somewhat dangerous because of the equipment used and the sharp stubble that remains on the site after cutting. This method may be suitable for releasing trees nearing crown closure from woody stems, but it does not control any of the herbaceous and grass competition.

Herbicides are also used to release crop trees from competing vegetation. Most herbicide research has been done with conifer regeneration; research into the use of herbicides in hardwood plantations is just now getting started. Herbicides generally do an excellent job of controlling woody vegetation, but the control over herbs and grasses is somewhat less, generally lasting from one to three growing seasons, depending on the site and the herbicide used. Most release operations using herbicides must be carefully scheduled after conifer trees go dormant, to minimize damage to crop trees. Many research studies have shown that herbicide release of conifer plantations does increase the survival and growth of crop trees.

The majority of the release studies undertaken by the Forest Vegetation Management Cooperative have involved testing herbicides on small plots in replicated trials. The main objective of a release herbicide is to provide good vegetation control without injuring the crop trees. Factors studied in release research trials include the herbicide formulation method, rate and timing of the application, and the influence of the phenological state of weeds and crop trees at the time of the herbicide application.

There are currently 10 active studies that are part of this project. In addition to field studies, the cooperative has conducted, and will continue to conduct, a herbicide efficacy survey. This survey is sent to forest vegetation managers annually, inquiring about their experiences with various herbicides. The information collected includes the results of site preparation and release herbicide applications, and is used to supplement data gathered from field studies.

Project 3: Investigate tree growth response related to vegetation control.

The primary emphasis of this project is the growth response of the crop trees to various vegetation management activities. Many research studies have shown that trees grown under weed-free conditions are bigger at the end of their rotation than trees growing with competing vegetation. Very few studies have been conducted that show the effect of vegetation management activities on the survival and growth of seedlings during the first 10-15 years after establishment. The cooperative currently has two ongoing studies which make up Project 3.

The first study measures the growth response of white spruce (Picea glauca (Moench) Voss) seedlings growing under overtopping aspen (Populus spp.) and released from overtopping aspen at the end of the second growing season. All trees on released plots were free-to-grow, having only grass and herbaceous competition. Four growing seasons after the released plots were sprayed, trees on released plots averaged only 1.2 cm more height growth than trees growing under the aspen. However, the free-to-grow white spruce had much larger diameters (25.2 mm) than the overtopped white spruce (16.8 mm). This study will be measured annually to provide the growth information needed to evaluate the cost effectiveness of releasing white spruce from aspen competition.

The second study making up Project 3 is the evaluation of the effect of different competing vegetation types on the survival and growth of white spruce. Four different treatments are applied to plots of planted white spruce. The treatments include:

1. No treatment (i.e., control plot) where naturally occurring grass, herbaceous and woody vegetation will be present on the site to compete with planted seedlings. Refer to as VEG plots;

2. Control woody stems, leaving herbaceous vegetation to compete with white spruce seedlings. Refer to as HERB plots;

3. Control herbaceous vegetation, leaving woody stems overtopping spruce seedlings. Refer to as WOOD plots; and

4. Total vegetation control where grass, herbaceous and woody vegetation are removed. Refer to as BARE plots.

Vegetation control was achieved using a combination of chemical and manual methods throughout the growing season. Seedlings (white spruce 3-0) were planted in the treatment plots at 7 x 7 foot spacing. There were 77 trees planted per plot, but only the inside 45 trees were used for annual measurements of survival, height growth and diameter growth. All of the plots receiving treatment 3 were accidentally over-sprayed with picloram in June of 1987; thus, the resulting vegetation on those plots is not what was desired, since many of the woody stems on those plots were controlled.

Survival after two growing seasons was the greatest on VEG plot (86%), followed by HERB plots (80%), with the BARE and WOOD plots at 64% and 60% respectively. There wasn't a significant statistical difference in height growth after two growing seasons, with growth ranging from 8.6 cm on the HERB plots to 10.7 cm on the BARE plots. The diameters of trees on the BARE plots (9.2 mm) were significantly greater than any of the other treatments (ranging from 5.1 to 6.4 mm).

Both 1987 and 1988 were drought years in the area where the study is located. Lower than normal rainfall and higher than

normal temperatures could account for some of the higher than expected mortality on the BARE plots. Both height and diameter growth were the greatest on trees in the BARE plots, in spite of low survival rates on these plots.

This study will continue to be monitored for the next several years to observe additional differences in tree response by treatment. Other study sites will be established in 1989 using red pine.

Project 4: Investigate forest vegetation management methods in relation to personal and environmental safety.

The Forest Vegetation Management Cooperative does not have any research studies in the project, due to the complex nature of these kinds of field trials. The idea behind this project was for the cooperative to search for and review research studies conducted by other organizations, and to make the information available to vegetation managers via information transfer activities.

INFORMATION TRANSFER ACTIVITIES

The other major function of the Forest Vegetation Management Cooperative is to inform resource managers about the efficacy, economic benefits, environmental impacts and personal safeness of forest vegetation management practices. This transfer of information is accomplished through hosting field workshops, making presentations at a variety of meetings, workshops and conferences, and writing publications and other reports.

ALTERNATE-STRIP CLEARCUTTING TO REGENERATE BLACK SPRUCE: WHY AREN'T WE USING IT MORE?

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ABSTRACT

This paper summarizes the results of research conducted on alternate-strip clearcutting by Forestry Canada in Ontario and discusses situations under which it may be a viable alternative to traditional clearcutting. The results of economic, biological, and environmental assessments are presented, and recommendations are made concerning increasing the use of alternate-strip clearcutting.

INTRODUCTION

The term 'strip cutting' has been part of forestry parlance in Ontario for several decades (e.g., Losee 1966). The earliest use of the term was in association with horse logging, in which skid roads that were one chain (20 m) apart were used to skid out the wood. The kind of strip cutting being considered in this paper is alternate-strip clearcutting with a two-cut system. The first cuts are naturally regenerated by seeding from the leave strips that are left for a few years. The leave strips are then cut and artificially regenerated, or cut and left to regenerate naturally.

This paper will summarize the results of a 13-year cooperative study to determine the biological and economic feasibility of alternate-strip clearcutting (see Robinson 1987, Smith 1989). The available evidence suggests that the alternate strip clearcutting system is biologically, environmentally and economically feasible and acceptable as a harvesting/regeneration system for mixed black spruce and black spruce/jack pine forests.

In the early 1970s, there was much concern about the status of regeneration in black spruce (Picea mariana (Mill.) B.S.P.) cutovers in the boreal forest. Then, it was estimated that

one-third of the area annually harvested was regenerated by artificial methods, one-third would regenerate naturally to acceptable stocking levels, and one-third would not regenerate to acceptable levels, at least for many years into the future.

At that time, Jim Fraser, then project leader for the Black Spruce Project at the Great Lakes Forestry Centre (GLFC, now Forestry Canada, Ontario Region), was assessing regeneration problems in upland black spruce cutovers (e.g., Fraser et al. 1976). One of the regeneration problems identified by George Marek, a forester in the Nipigon/Domtar forest, centred on the black spruce shallow-soil ecosystem, a common type in the Canadian Shield. When clearcut, these sites present a formidable problem for artificial regeneration as a result of planting difficulties and poor survival of seedlings after planting. As well, there are potential adverse environmental impacts on the hydrology, soils, and nutrient balance and loss after harvesting.

It is well known that black spruce can, under the right conditions, regenerate naturally from seed if one reduces the size of the clearcut. One harvesting/regeneration system that utilizes natural regeneration from seed is alternate-strip clearcutting, a system developed long ago in central Europe that has been applied sporadically in Ontario and elsewhere in Canada. The main factors that favour successful regeneration by means of this method are adequate seed supply, receptive seedbed and protection of the regeneration by adjacent leave strips.

In 1973, the Nipigon District Office of Ontario's Department of Lands and Forests (now the Ministry of Natural Resources, OMNR), was prescribing the alternate-strip clearcutting technique for shallow-soil black spruce in the Nipigon Forest. The rationale for doing this was to provide at least some black spruce regeneration for cutovers that were not included in the planting program.

However, there was strong resistance from Domtar, the licensee. The company was not convinced that the system worked, or that enough was known to make it work with high reliability. They also believed that they were not being compensated enough by

the province for the additional costs of undertaking strip cutting. At that time the Department of Lands and Forests was paying the company compensation for extra costs incurred by strip cutting, but this compensation was based only on rough estimates. Clearly, research was needed to answer the questions of reliability and cost, and GLFC was in a position to provide unbiased, scientific assessments.

Consequently, the province and Domtar requested that GLFC undertake studies of strip cutting. A formal agreement was developed between the three agencies, which defined the roles and actions required by each. The study objective, in general terms, was to determine if strip cutting was an economically and biologically acceptable method of harvesting and regenerating black spruce on shallow-soil upland sites.

ECONOMICS ASSESSMENT

The first economics studies were to define the extra costs of harvesting in strip cutting compared with those of clearcutting (Ketcheson 1977, 1979, 1982; Ketcheson and Smyth 1979). The work resulted in estimates of the additional costs (Table 1), and these estimates were actually employed by Domtar and the province to determine compensation rates.

A second economics study dealt with the total costs of strip cutting as a complete system of harvesting and regeneration (Johnson and Smyth 1987, 1988). Numerous scenarios of planting and direct seeding were compared for strip cutting versus clearcutting (Figure 1). In this figure, bars that project to the right represent comparisons in which the clearcuts are planted and the second-cut strips are artificially regenerated by planting or seeding. With these options, and a leave period of 3 to 5 years, it is possible to achieve net savings of between $200 and $600 per hectare by strip cutting!

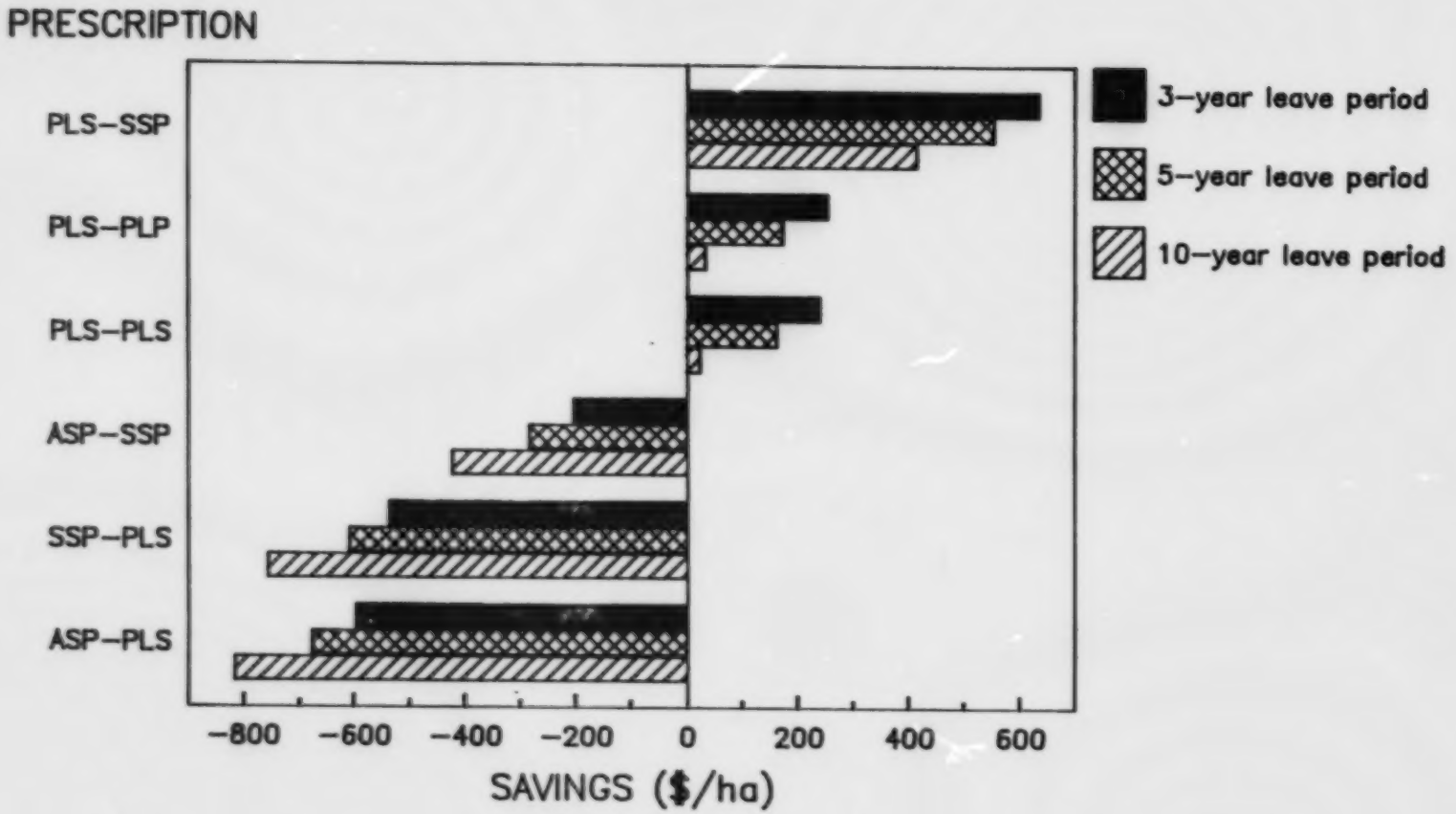

Figure 1. Net harvesting and renewal savings, comparing clearcutting with strip cutting (from Johnson and Smyth [1988]). The width of both the first and the second cut strips is 60 m, the depth 180 m (360 m was also calculated). For the various regeneration comparisons, the first acronym represents the clearcut option, the second the strip cut option. PLS = plant black spruce, PLP = plant jack pine, SSP = seed spot pine, ASP = aerial seed pine. Not all options are presented.

Table 1. Summary of estimates of extra costs ($/ha cut) of strip cutting compared with clearcutting (from Ketcheson [1982]).

Leave period	3-year	5-year	10-year
	----------($/ha)----------		
Planning and layout	12 - 24	12 - 24	12 - 24
Slashing, movement of men and equipment	6 - 14	6 - 14	6 - 14
Road (non-Clay Belt)	37 - 38	65 - 73	102 - 154
TOTAL	55 - 76	83 - 111	120 - 192

On the other hand, the bars that project to the left in Figure 1 represent comparisons in which the clearcuts are artificially seeded, and with these options it is clearly cheaper to clearcut and seed than to strip cut. However, one must switch to jack pine (Pinus banksiana Lamb.) for this option, because aerial seeding with black spruce is not reliable with current methods. Forestry Canada, Ontario Region is currently conducting studies to determine how to regenerate black spruce successfully by direct seeding (Fleming and Groot 1984).

We can extrapolate from the economics study to estimate the potential savings on a province-wide basis. With an annual harvest in Ontario of 220,000 ha, the area of black spruce sites eligible for strip cutting is estimated to be around 22,000 ha per year. (This is based on the assumptions that 40% of the annual harvest consists of the black spruce working group, and that 25% of this consists of poor, shallow-soil and wet organic sites, located far from the mill or the road.) If we compare the options of 'clearcut and plant' with 'strip cut and plant the second-cut strips' (Johnson and Smyth 1987, 1988), the annual renewal savings are $9.2

million, and the net harvesting and renewal savings are $4 million. Of course these savings assume that the fragile black spruce sites are being addressed in the planting program. This may not generally be the case since the usual practice is to plant the best sites first. It may be possible to address more of the harvested area more efficiently if the regeneration dollars are spread among a mix of high-priced planting techniques, medium-priced modified harvesting techniques such as strip cutting, and low-priced techniques such as direct seeding. Economics studies and simulations may be useful to determine the costs of different mixes of regeneration techniques, and to help determine the most effective allocation of regeneration dollars.

BIOLOGICAL ASSESSMENT

Another main objective was to determine the biological effectiveness of strip cutting as a means of regenerating black spruce on fragile upland sites. This was addressed in a major strip cutting regeneration experiment (Jeglum 1980, 1982, 1983, 1984, 1987). Results from this study indicated that strip cutting, when done with the right combination of strip widths, leave time and site preparation, has a fairly high probability of achieving either acceptable or desirable levels of black spruce regeneration.

As a generalization for the whole study, stocking levels (%) in the low 50s were achieved in the 2-year leave strips, whereas levels in the low 60s were achieved in the 4-year leave strips. Another way to express the reliability of strip cutting is by the proportions of strips (40- and 80-m, 20-m excluded) in which different levels of stocking were achieved (Figure 2). The proportions of strips in which failure levels (<40%) or acceptable levels (40 to 59%) were achieved were higher for the 2-year leave strips, whereas the proportions of strips in which desirable levels where achieved (≥60%) were higher in the 4-year leaves.

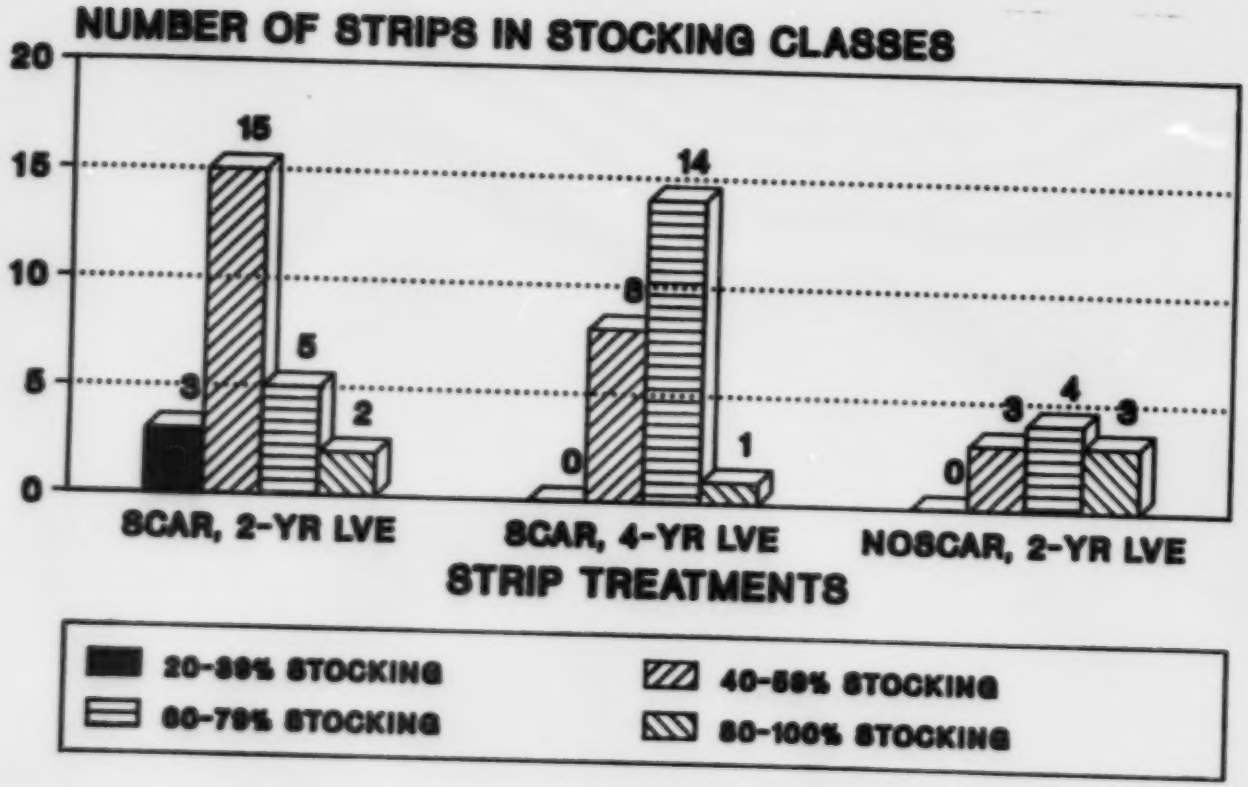

Figure 2. The numbers of strips in which various levels of black spruce stocking were achieved at the fifth-year assessment. Strips tallied are the 40- and 80-m strips in the three study areas of the Nipigon/Domtar Strip Cut Experiment.

It is noteworthy that acceptable or higher levels of stocking were achieved in two-thirds of the nonscarified control strips, a rate of failure of only one-third (Figure 2). This may have been a result of less damage to advance growth and less destruction of Sphagnum, both of which occur during site preparation. This suggests that if there is a reasonably high component of advance growth in the stand, one option to regenerate the second-cut strips could be to use careful logging to preserve advance growth (see Wood and Raper (1987) for other options).

In addition to the documentation of regeneration, there was concern about the magnitude of losses incurred from blowdown at the strip borders. A study of windfall and mortality in strip cuts was conducted, which quantified the amount of blowdown that occurred in the leave strips over time (Fleming and Crossfield 1983). This work was used in assessing the additional costs of strip cutting.

ENVIRONMENTAL IMPACTS

A number of other studies were undertaken to assess environmental impacts, the last main objective. These included studies of hydrology (Nicolson 1988), soils (Jeglum 1980), nutrient balance and loss (Foster and Morrison 1987), and moose browse (D.A. Welsh, unpublished data). Some of this research has provided information for the Class Environmental Assessments for forestry.

STRIP CUT WORKSHOP

In 1986, a workshop was held to summarize the findings of the project (Jeglum 1986). The workshop consisted of a day of presentations and discussions, followed by a field trip on the second day. The workshop was well attended by forest managers from industry and OMNR, and discussions focused on practical applications. The papers and recommendations that resulted from the workshop have been published in the Forestry Chronicle (see list of publications, end of this paper).

Time does not allow for a complete summary of strip cutting technology. However, I would like to emphasize a few points which seem particularly relevant to this workshop on 'site-specific tools'.

On Site

On shallow-soil sites one is dealing with a highly variable mixture of site conditions, all of which are united by the extremely shallow mineral soil component over bedrock (Jeglum 1980, Sims and Towill 1988). These may include dry exposed bedrock, bedrock covered with only a mor forest humus and feathermoss, variable depths of shallow ground moraine over bedrock, and wet undrained bedrock bowls and drainageways with peaty deposits. Sometimes these areas can be rather flat and low with a predominance of lower slope and wet peaty conditions. In other places the areas may be very rugged and broken, with rocky outcrops and crest and upper slope conditions predominating. Sometimes there may be a 'ribbed' pattern, with low ridges of rock alternating with wet peaty swales. Boulder outwash is another fragile, shallow-soil site that is particularly difficult to regenerate by conventional planting techniques.

Even though strip cutting is a technique for poorer sites, the system will definitely work on better black spruce sites. In fact, the Nipigon experiment was conducted on sites that were considerably better, with more soil, than the most extreme shallow-soil sites that were originally intended to be harvested by the strip cutting system (Jeglum 1980).

On Planning and Implementation

Strip cutting will require more planning and scheduling than clearcutting (Morrow 1988). More detailed air photo interpretation is required to lay in the road systems, and the air photo interpreter should follow up his interpretation with field checks to coordinate road and strip layouts. With the advent of feller bunchers, it is possible to increase the depth of the strips to 400

m from the previous 200 m, thus reducing the total length of the road system. Often the stands identified for strip cutting are intermixed with other blocks that will be clearcut. In these cases the supply of wood may be evened out by combining strip cutting with clearcutting in the harvesting area.

In laying out the strips, there must be room for variation from a strict application of fixed widths and depths of strips (Morrow 1988). Irregular patterns and designs of the first cut and leave strips or blocks may be used to adjust to the usually variable topography. First cut strips might be the intermediate slopes and the second cuts could be the higher bedrock knobs and wetter Sphagnum-rich swales. The second cuts could be harvested by careful logging to preserve advance growth and small trees, which are often more abundant in the more open wetter and drier sites.

. The standard operational strip width in the shallow-soil upland sites in the Domtar operation is 60 m. However, if the site is very rocky and rugged, and site preparation will expose a high proportion of bedrock, widths should be reduced to (say) 40 m, to increase the amount of shelter provided by the adjacent leave strips. If the site is predominantly wet, with lots of Sphagnum, the width could be increased to 80 or 100 m. It is possible to make the leave strips narrower in order to obtain a higher proportion of inexpensive natural regeneration in the first cuts. If the leave strips are on extremely rugged knobs with poor volumes, they should be left uncut.

On Maintaining Site Productivity

The shallow-soil upland ecosystem is particularly susceptible to deterioration of site productivity. A high proportion of the nutrient reserves are in the living biomass and the organic mat, which must be treated with care to avoid exposing the thin underlying mineral soils to erosion. As well, removal of the slash from the site will significantly reduce the total nutrient storage of the site (Foster and Morrison 1987).

The current practice of full-tree harvesting concentrates the slash and the nutrients contained therein into piles at the heads of strips. This may lead to a decrease in site productivity (Rosén and Lundmark-Thelin 1987). Another problem is that the slash piles may be difficult to burn completely, and some of the piles may never become fully regenerated. Finally, if jack pine is present as a component of the stand, the slash/cones are removed from the site in slash and cannot provide additional conifer content in the natural regeneration. Therefore, it is recommended that on normal shallow-soil sites, tree-length harvesting systems should be used in preference to full-tree systems.

On the other hand, when stands have full crowns and the potential for producing heavy slash, which usually occurs on deeper soils, it may be necessary to use full-tree logging with delimbing at roadside in order to obtain adequate site preparation. It may not be possible to change the methods of harvesting with existing machinery, and if there is a choice between getting regeneration or guarding against possible loss of productivity, it is clear that regeneration must come first.

Concerning site preparation, I have recommended that the Sphagnum-dominated areas, and areas that have abundant advance growth, should be passed over by lifting the scarification tool (Jeglum 1983). Scarification of these areas will usually result in destruction of the advance growth and of receptive Sphagnum seedbed. These areas should be flagged and machine operators should be trained on how to recognize them.

Conservation of the organic mat and other organic reserves is extremely important on shallow-soil sites. When scarifying mineral soil uplands, one should apply 'delicate' as opposed to 'radical' scarification (e.g., Johansson 1987). Studies in GLFC's Black Spruce Ecosystem Silviculture Project have shown that one should aim at exposing the interface between the top of the mineral and the bottom of the organic mat (Fleming and Groot 1984).

WHY AREN'T WE USING STRIP CUTTING MORE?

The history of the strip cutting project has been one of providing facts and alleviating concerns about potential problems with the use of this harvesting/regeneration system. We know a great deal more now than at the beginning of the project, but there are still concerns about the system.

With regard to regeneration, foresters may still be concerned about the probability of success in obtaining adequate regeneration: that the natural seedlings take much longer to get established and have slower early growth rates in comparison with planted stock; and that the spacing of individuals in the naturally regenerated stands may be too sparse, too dense or too aggregated. (If one regards black spruce as a pulpwood species, dense spacing is probably not a major concern.)

With regard to planning, foresters may still worry about the extra work in photo interpretation, planning and laying out roads and side lines; problems with scheduling harvesting in relation to mill requirements; and problems with returning to areas for the final harvest cuts. However, the additional planning may in fact provide some advantages by identifying opportunities for modified harvest and by better integration of the harvesting and regeneration efforts to achieve the most economical system.

With regard to economics, limited regeneration dollars may create concerns about whether to invest only in the most expensive planting approaches, or if it is more efficient to spread the regeneration dollar among high-, medium- and low-cost regeneration methods. It may be that for certain of the medium-to-poor sites it is not a good investment to undertake expensive planting programs, and that modified harvesting or direct seeding are most appropriate. The regeneration strategy will depend on the supply of seedling stock and the specific mix of site types, forest types and the relative abundance of advance growth (as this relates to careful logging techniques for the second cuts).

Certainly, there are opportunities for research to answer these questions, but at this stage the most important need is for more general operational use of strip cutting as part of the harvesting/regeneration plan. We are at the stage where we know the system works, but we need to develop skill and finesse in its application to achieve optimum results. In addition, the industry and OMNR should be carefully and systematically monitoring and documenting the results of the existing operational strip cuts to continue to build up a store of knowledge of how the system works with various modifications and different site and weather conditions. Finally, it should be recognized more generally that the extra cost of modifying harvesting to achieve regeneration is a regeneration cost. Accordingly, we should develop appropriate mechanisms in FMAs that encourage, not penalize, the use of strip cutting.

CONCLUSIONS

The Nipigon/Domtar strip cutting project has shown that:

1) Strip cutting is biologically feasible, and can be applied successfully by using the correct strip width, leave time and site preparation;

2) When considering either renewal costs or the total costs of harvesting and regeneration, strip cutting is considerably cheaper than clearcutting and planting; and

3) With limited regeneration dollars, and ceilings being placed on the number of seedlings that can be produced, natural regeneration by strip cutting should be utilized more as a medium-priced system to regenerate black spruce.

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WOOD QUALITY: WHAT IT IS AND HOW IT IS INFLUENCED BY FOREST MANAGEMENT PRACTICES

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ABSTRACT

It is important that forest managers understand all of the ramifications of the silvicultural treatments they choose. Regardless of whether extensive or intensive management options are selected, the actions of forest managers have a direct impact on the physiological condition of the trees on a site. This ultimately controls properties of the wood produced by the trees. The fact that many individual wood properties interact to determine quality makes it difficult to predict how changes in a particular property will influence the end-product. As a result, it is necessary to either conduct many long term silvicultural experiments and produce empirical models or develop theoretical methods for predicting how silvicultural treatments will influence wood properties. Forintek, in cooperation with PAPRICAN, the British Columbia Ministry of Forests and others, has developed a system of computer models that can be used to predict wood properties and value from silvicultural information. This method has been used on coastal Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco), and attempts are under way to produce a similar set of models for jack pine (Pinus banksiana Lamb.).

INTRODUCTION

Stocking control, through initial spacing, juvenile respacing or vegetative management, is likely to become the most widely used silvicultural method for enhancing growth rates of Northern Ontario forests. The impact of various methods of stocking control on the wood quality of principal softwood species in this region, i.e., black spruce (Picea mariana (Mill.) B.S.P.), jack pine (Pinus

banksiana Lamb.), balsam fir (Abies balsamea (L.) Mill.) and white spruce (Picea glauca (Moench) Voss), is not well understood. In this paper, the effects of initial spacing and early respacing on the wood quality of black spruce and jack pine will be discussed. Selected data for these species will be used from the studies currently under way at Forintek, as well as that available in the literature. Supplemental information will be presented on other species, as it is needed, to round out the discussions.

Finally, a computer-based modelling system, known as SYLVER, will be briefly described. SYLVER is a stand level model which predicts wood quality and end-product value from silvicultural information. At present, the only SYLVER model which exists is for coastal Douglas-fir. Forintek is currently attempting to generate interest in developing a similar model for jack pine.

Definitions of wood quality

There are a number of definitions of wood quality. Mitchell (1961) coined one of the most often quoted and paraphrased definitions in the wood science literature: "Quality is the resultant of physical and chemical characteristics possessed by a tree or part of a tree that enable it to meet the property requirements for different end-products. In other words, the intrinsic quality of wood evaluated solely in terms of its suitability for various products or end uses." This definition provides forest managers with a concept, but not the specific information they need. It says nothing about which wood properties determine quality, and as a result, forest managers can derive little benefit from such a definition unless it can be translated into specific management objectives.

Wood scientists are cautious about committing themselves to specifics because the length of time it takes to grow a crop of trees makes it likely that changes in product mix and technology might render their prescriptions obsolete by the time the trees are harvested. There is, however, a set of wood properties for coniferous woods which have always been recognized as "good" and

a corresponding set recognized as "bad." Maintenance of relative density at an acceptable level for the species, a high level of dimensional stability, a large sapwood area (for treatability and pulpability), long fibres, good mechanical properties (both of wood and fibres), and high alpha-cellulose content are considered positive qualities. Large knots and high knot volumes, spiral grain, high microfibril angle, low permeability, compression wood, high lignin content, crooked stems, and excessive taper are thought of as poor characteristics.

Many wood properties are controlled by the physiology of the tree; the condition of the crown is particularly important in this respect (Larson 1969). Unfortunately, crown characteristics that encourage rapid growth are also thought to be detrimental in terms of quality. As understanding of the physiological control of wood quality becomes more complete, the ability to maintain high quality and still achieve growth objectives improves. Before it will be possible to understand the control of wood quality through modification of tree physiology, the wood properties which respond to silvicultural treatments need to be identified. The following sections will survey changes in selected wood properties that are known to influence the suitability of softwoods for a large number of end-products, under a wide range of manufacturing technologies.

EFFECT OF STOCKING CONTROL ON WOOD PROPERTIES

Stem Form

In general, open-grown trees have greater taper than stand-grown trees (Larson 1963). Increased taper can result in errors in volume estimates. It will also lead to more wane, which is one of the most important causes of degradation in lumber. Other adverse affects of wider spacings on stem form include increased crook, fork, sweep and lean (Timell 1986 p. 1682). These defects are potentially more damaging than taper because they promote development of compression wood, make debarking more difficult, reduce lumber recovery and preclude the use of roundwood for poles and pilings.

No data were found on the spacing or stem form of black spruce, while limited data exist for jack pine. Adams (1928) presented data on stem radius at various heights from several spacings which suggest that taper increases with wider spacing in jack pine. Buckman (1964) on the other hand, found little difference in form quotient between spacings 22 years after a precommercial thinning carried out at age five.

Several studies have considered changes in stem form in immature jack pine stands with increasing spacings (Ralston 1953; Guilkey and Westing 1956; Godman and Cooley 1970; Bella and De Franceschi 1974, 1980; Janas and Brand 1988). Bella and De Franceschi (1974) found that in 11-year-old trees, stem deformities increased with spacing distance. At spacings of 1.2 m, approximately 10% of the stems had some type of defect, e.g., forks, crook, excessive sweep, etc.; while at 3.3 m, 20% of the stems had one or more defects.

Janas and Brand (1988) evaluated stem form in a naturally regenerated jack pine stand, which initially contained more than 10,000 stems/ha; as well as in plantations established at 2.1 m and 4.3 m spacings. Stem quality was ranked based on the presence of crooks, forks, sweep and knot size. On a scale of one to five, with five being the worst stem quality, the rankings were: 2.05 for the natural stand, 2.88 at 2.1 m and 3.01 at 4.3 m. Janas and Brand felt that the best stem quality would result from natural regeneration or direct seeding followed by a precommercial thinning. This method offers the advantage of reducing stand establishment costs, allows the best stems to be selected during the thinning and provides for the use of improved seed as it becomes available.

Knot Size

Branch size has been shown to be positively related to initial spacing in jack pine, and the importance of maintaining small knots and good form for sawlog quality is clearly recognized in forestry literature (Janas and Brand 1988; Bella and De Franceschi 1980; Godman and Cooley 1970; Guilkey and Westing 1956; and Ralston 1953). The fact that stem quality is also important in pulpwood does not seem to be as well understood. For example, Godman and Cooley (1970) state that, "...9 x 9-foot spacing seems more acceptable than anticipated... provided bole straightness and limb size are not critical." Bella and De Franceschi (1980) concluded that, "The poor form, multiple leaders, and heavy branches that developed in jack pine at wide spacing preclude the production of better quality sawlog material, although the trees may be suitable for other uses."

These types of statements demonstrate a lack of sensitivity to the characteristics that cause quality problems in pulp mills. Crooked stems are difficult to debark, and bark reduces pulp quality and increases bleaching costs. Crooked stems also contain compression wood (Timell 1986 p. 1314-1317), and high compression wood contents are known to result in poor pulp properties (Pillow et al. 1936; Ladell et al. 1967; Timell 1986 p. 1831-1892). In terms of branch size, one rule of thumb is that knot volume can be subtracted directly from the volume of the wood entering the pulp mill (Hatton 1989, personal communication). In young loblolly pine (Pinus taeda L.) von Wedel et al. (1968) have shown that the amount of compression wood associated with knots is between 4.5 and 18 times the volume of the knots. In addition, Axegard and Teder (1977) reported that morphological knot particles were the most difficult to remove by bleaching.

The effects of spacing on branch or knot size in black spruce do not seem to have been considered in the literature. Information on the influence of spacing on branch size in Norway spruce is, however, quite common. Laasasenaho (1988) has reported that for Norway spruce (Picea abies (L.) Karst.) and Scots pine (Pinus

sylvestris L.) there is "a linear relationship between the cross sectional area (basal area) of the stem and the cumulative cross sectional area of the branches." Nylinder (1959) found that in Norway spruce, wider spacings resulted in larger branches below three metres in height; but above this height no difference was found.

Klem (1952) studied the sulfite pulping properties of Norway spruce at five spacings ranging from 1.25 to 3.5 m. Tear strength declined from the narrowest to widest spacing. Tensile and burst strength increased with ring width up to a growth rate of 3.5 mm, but declined after that. Klem (1952) judged that the effects of increased spacing became detrimental at growth rates above 4 mm per year. This occurred at a spacing of 2.5 m. Klem reported that production of one tonne of sulfite pulp would require 4.7 m^3 of wood from a 1.25 m spacing, and 6.7 m^3 of wood from a 3.5 m spacing. This represents a 42.5% increase in the volume of wood required for a similar pulp yield.

Relative Density

Klem (1952) felt that much of the variation in properties of Norway spruce at various spacings was due to differences in relative density brought about by changes in growth rate. A negative relationship between growth rate and relative density has long been suspected for many species, and this relationship has been fairly well established for Norway spruce (Aldridge and Hudson 1958). Olesen (1976) has shown that the relationship is not linear but is parabolic in shape. Whether similar relationships exist for the coniferous species grown in Northern Ontario is still a matter of debate. Hale was emphatic about the existence of a negative relationship between growth rate and relative density (Hale and Brophy 1923; Hale 1924; Hale and Prince 1940; Hale 1959), even suggesting the parabolic relationship (Hale 1924; Hale 1959) well before Olesen (1976).

Hale and Prince (1940) published data supporting a negative relationship between growth rate and density for balsam fir, black spruce and white spruce. Their data were, however, much more convincing for white spruce than the other two species. Keith (1961) subsequently demonstrated that there is a linear relationship between growth rate and relative density in white spruce, with a negative slope and a r^2 which decreases from 0.42 to 0.16 as samples further from the pith are measured. If a linear regression is run on the white spruce data published by Hale and Prince (1940), a r^2 of 0.38 is obtained (Barbour 1988, p. 6). Thus, it seems safe to conclude that for white spruce a relationship with a r^2 of something less than 0.40 might be expected depending on the age of the trees studied. Keith's data suggest that the relationship will be considerably weaker in older trees.

In jack pine and black spruce, available evidence indicates that growth rate, per se, has very little influence on relative density. Hale and Prince's (1940) data for black spruce has a substantial amount of scatter, showing at best a very weak relationship. Using X-ray densitometric data, Barbour (1987) and Barbour and Chauret (1988) found no relationship between growth rate and relative density for either juvenile or mature wood in 16 black spruce trees.

Keith and Chauret (1989) could not detect a relationship between tree volume and relative density for even-aged progeny of randomly selected Ottawa Valley jack pine. Maeglin (1967) found that there was no significant difference in relative density for jack pine planted at spacings between 0.6 x 0.6 m and 2.4 x 2.4 m, concluding that the 1.8 m spacing was the most economical, based on weight yield. Hunt (1977) found that relative density for thinned jack pine was essentially the same as that for untreated control trees. Kraft pulp yields were also nearly identical in these two groups, indicating that relative density was a good indicator of pulp yield and that no major change in chemical composition of the wood had occurred as a result of the treatment.

Although clear relationships between growth rate and relative density can be difficult to discern, this does not mean that there will be no difference in density between trees from a natural population and those from a managed population. Table 1 shows a comparison of data collected by Forintek for black spruce (Barbour 1987; Barbour and Chauret 1988) and jack pine (Keith and Chauret 1986) with those published by Jessome (1986). Jessome's data are regarded as the standards for averages for trees from natural stands. The Forintek data are whole tree density values representing relatively young fast-grown trees, similar to those which might be expected from managed stands. Comparison of the 95% confidence intervals reveals that the means for the fast-grown trees of both species are significantly lower than those reported by Jessome (1986).

Table 1. 95% confidence intervals for black spruce and jack pine relative density.

Species	Source of Data	Variance	Sample Size	Mean	95 Percent Confidence Interval Low	High
Black Spruce	Jessome	0.00146	216	0.406	0.401	0.411
	Forintek	0.00050	16	0.380	0.369	0.393
Jack Pine	Jessome	0.01370	309	0.421	0.417	0.425
	Forintek	0.00021	10	0.395	0.385	0.406

In both species, density was about six percent lower. Therefore, approximately six percent more wood volume will be required from these rapidly-grown trees to provide a fibre yield equivalent to that obtained from a similar volume harvested from a natural stand.

Figures 1 and 2 show the average pith to bark relative density profiles for the trees represented in Table 1. The solid lines outlining the data points are 95% confidence intervals for the segmented regression model, shown by the solid line drawn through the data points. Details of how these segmented regression models were obtained are given by Cook and Barbour (1989). Figure 1 is an average breast height pith to bark relative density profile for the black spruce. Barbour et al. (1989) have presented data indicating that this pattern is related to the vigour of the branches at the height from which the density samples were taken.

Relative density is highest near the pith and decreases until about 17 rings from the pith. Beyond this age the relative density increases slightly but never approaches the values observed in the first 5 to 10 rings. This is quite different than the more widely recognized situation, found in Douglas-fir and many pines, where the density of juvenile wood is lower than that of mature wood.

The pith to bark relative density profile for jack pine (Figure 2) is more typical of what has been reported in the literature for other species. Except for the few high density values close to the pith, density increases from the pith towards the bark. All of the rings shown in Figure 2 are probably juvenile wood. Keith has been performing segmented regression analysis on a large number of older jack pine trees and has found that when a clear demarcation exists between juvenile and mature wood, it tends to occur at more than 30 rings from the pith (Keith 1989, personal communication).

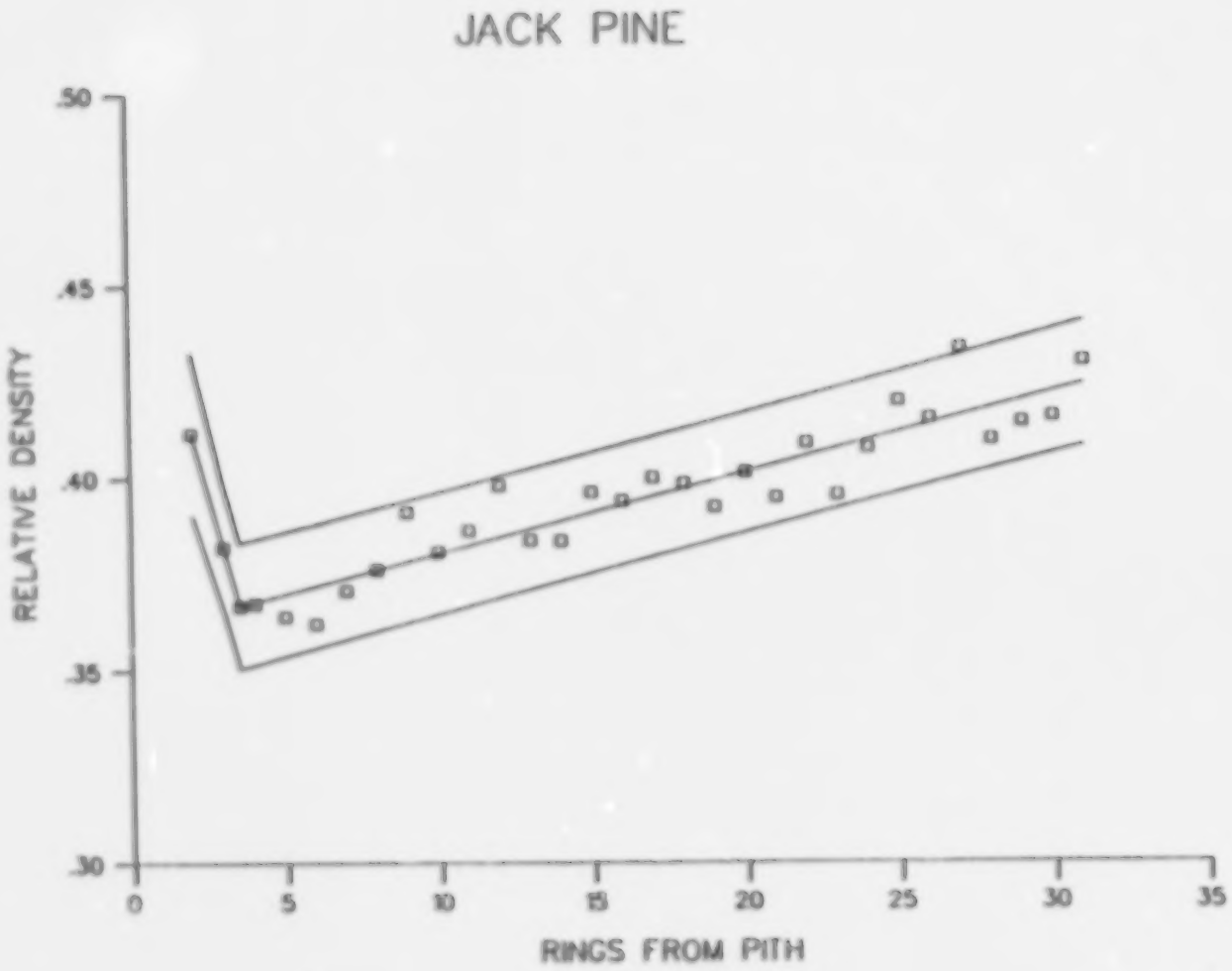

Figure 1. Jack pine breast height relative density profile mean of 10 trees from data collected by Keith and Chauret (1986).

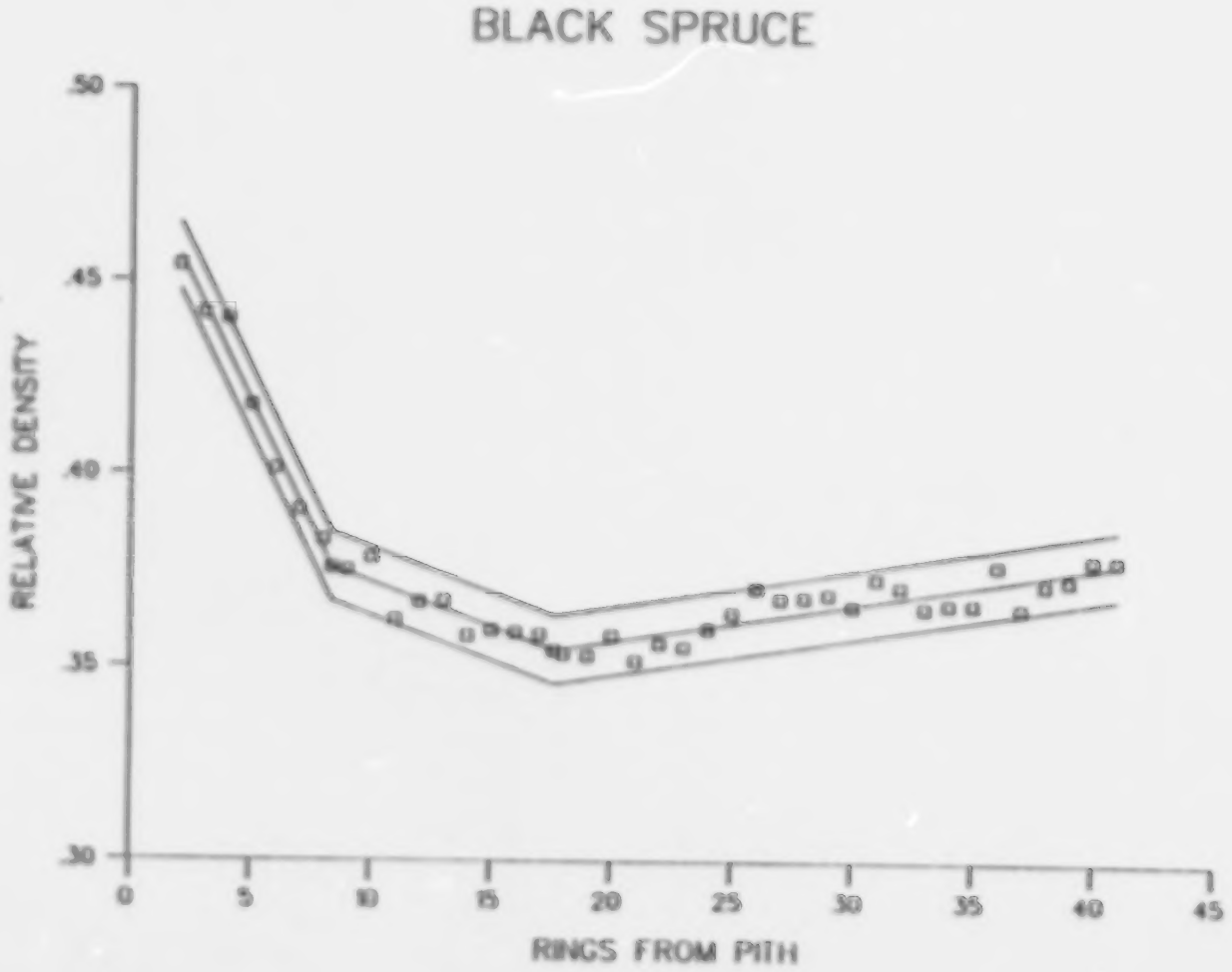

Figure 1. Black spruce data collected by Barbour (1987) and Barbour and Chauret (1988) showing mean breast-height relative density profile for 16 trees.

Fibre Characteristics

In general, tracheid length in conifers increases from the pith towards the bark. After a number of years it will reach a plateau (Sanio 1872) or begins to oscillate (Shepard and Bailey 1914; Bailey and Shepard 1915). Within a given growth ring, tracheid length increases with height until it reaches a maximum. Above this height it may decrease (Sanio 1872) or oscillate (Shepard and Bailey 1914; Bailey and Shepard 1915). Similar trends are seen in both jack pine (Kribs 1928) and black spruce (Lee 1950; Sebastian 1970). In both of these species there is a rapid increase in fibre length in the first 10 to 15 rings from the pith, followed by a more gradual increase which, for practical purposes, continues for the remainder of the tree's life. Although it has never been demonstrated, it seems likely that the initial rapid increase corresponds in some way to the recession of the crown. If this hypothesis is correct, then tracheid length will be expected to remain low for as long as the crown is vigorous at a given height level. Thus, wider spacing might have a negative impact on tracheid length.

In the case of black spruce, tracheids closer to the pith are narrower, having walls which are thicker in proportion to their total width than those in rings further from the pith (Green 1968; Ladell 1970). Olesen (1977) has shown that in Norway spruce, such changes in tracheid morphology influence the pith to bark relative density profile. The results presented in Figure 1, as well as the findings of Green (1968) and Ladell (1970), indicate that this is also the case in black spruce. Thus, Figure 1 suggests that the fibre produced from fast-grown black spruce may be quite different than that found in the current resource.

In trees of equal diameter, the rings near the pith account for a larger proportion of total volume in fast-grown trees than in slow-grown trees. As a result, fast-grown trees will have a higher proportion of shorter, stiffer tracheids than slow-grown trees. Such tracheids do not collapse as easily as large diameter, thin-walled tracheids, and result in high bulk and fold endurance

in paper (Watson et al. 1952). Ladell (1970) found that the tensile and burst strengths were negatively related to the radial thickness of the latewood tracheid walls. Tear strength was positively related to the cell wall percent.

Microfibril Angle

There has apparently been no research on the effect of spacing on microfibril angle in black spruce or jack pine. Hiller (1954) has produced pith to bark microfibril angle profiles for slash pine (Pinus elliottii Engelm.) trees with varying growth rates. In slow-growing trees there was a curvilinear relationship between microfibril angle and rings from the pith. In fast-growing trees the relationship was linear. Data collected by Barbour et al. (1989) for fast-growing black spruce are quite similar to Hiller's data for fast-growing slash pine, but no corresponding data exists for slow-growing black spruce. If the analogy between the two species is complete, increased growth rates in black spruce could have detrimental effects on mechanical properties of both lumber (Mark 1967, p. 168; Schniewind and Barrett 1969) and paper (Watson et al. 1952).

A great deal of work has been done on the relationship between microfibril angle and longitudinal shrinkage in wood (Meylan 1972). Much of this work was done on radiata pine (Pinus radiata) and Jeffrey pine (Pinus jeffreyi Grev. and Balf.), and several mathematical models were derived to predict longitudinal shrinkage from microfibril angle (Barber 1968; Cave 1969, 1972). These models and the data collected for radiata and Jeffrey pine predict, more or less, the constant longitudinal shrinkage for microfibril angles up to about 35°, after which there is a substantial increase in longitudinal shrinkage and corresponding decrease in tangential shrinkage.

Data collected for black spruce (Barbour et al. 1989) agree with those for radiata pine in that longitudinal shrinkage is more or less constant at low microfibril angles, but at higher microfibril angles shrinkage in this species becomes quite variable

and does not show a clear trend. Preliminary data concerning the relationship between longitudinal shrinkage and microfibril angle in jack pine show a relationship which is quite similar to that found for black spruce.

These results indicate that in black spruce and jack pine the relationship between microfibril angle and longitudinal shrinkage is not a simple one. It can, however, be concluded that increases in microfibril angle can generally be viewed as detrimental, particularly when microfibril angles exceed about 30°. Hiller's (1954) data for slash pine indicate that in fast-grown trees a higher proportion of the tracheids will have microfibril angles in this category than in slower-grown trees.

Heartwood Content

The heartwood content of wood is important in the manufacture of pulp and paper, as well as lumber. Decreases in heartwood content with increased spacing will probably be more important for jack pine than black spruce. Heartwood extractives cause problems in both mechanical and sulfite pulping of jack pine (Paterson 1937; Jossart et al. 1988), while they are not considered a problem in black spruce. Any increase in the sapwood content of jack pine will also be favourable for the production of preservative-treated lumber and poles.

In general, faster-growing trees with larger, more vigorous crowns have a higher proportion of sapwood (Wellwood 1955; Smith et al. 1966; Wellwood and Juraza 1968; Millis and Ditchburne 1974). Yang et al. (1985) found that for jack pine there was apparently no relationship between sapwood radial growth rate and sapwood thickness. The data used in this analysis were, however, pooled for all heights. Further analyses of these data show that absolute sapwood width at a single height level increases as growth rate increases in jack pine (Yang 1989, personal communication).

Kaufmann and Troendle (1981) reported that sapwood area was related to the leaf area in the crown. They explained that sapwood area decreases with height because as height increases,

particularly within the live crown, less leaf area is served by the sapwood at that height level and therefore less sapwood is needed. This explanation seems quite plausible and agrees with much of the published data on sapwood area and crown vigour (Wellwood 1955; Smith et al. 1966). It therefore seems safe to conclude that as spacing, leaf area and growth rate increase so will sapwood content.

Compression Wood

Pillow et al. (1936) found that compression wood is quite common in the lower portions of black spruce stems. Sixty to 80 percent of the trees from two stands contained compression wood at stump height. At the top of the first 8-foot log only about 25% of the trees had compression wood, and above this height about 10% of the trees contained this defect. They also felt that the compression wood from the lower parts of the stem was of a more severe form than that higher in the stem. Ladell et al. (1967), in a detailed study of 11 black spruce trees, found that compression wood content tended to be highest near the stump and in the upper parts of the crown. Results from a study conducted at Forintek on straight, fast-grown black spruce without lean (Barbour and Chauret 1988) generally agreed with this conclusion.

Ladell et al. (1967) found that straight black spruce stems contained a volume weighted average of 13.9% compression wood. Barbour and Chauret (1988) found compression wood in all stems examined, but it was generally of a mild form which was not expected to have a large influence on the mechanical properties of lumber. It was, however, demonstrated that even this mild compression wood could influence longitudinal shrinkage (Barbour 1987).

Groundwood pulps made from black spruce compression wood contained large amounts of fines or fibre fragments (Pillow et al. 1936). These pulps also had lower freeness and strength properties than pulps produced from normal wood.

Ladell et al. (1967) studied the sulfite pulping of black spruce compression wood. Using regression analysis, they determined that 55% of the variation in pulp yield among 68 pulp trials could be accounted for by compression wood content. Additional pulping trials with samples containing various percentages of compression wood showed that the yield from chips containing 30% compression wood was only 85% of that from normal wood at the same Kappa number. Tensile strength declined more or less linearly with increasing compression wood content to about half the normal wood value in pulps made from 100% compression wood. Burst strength, on the other hand, increased in samples containing 5 and 10% compression wood, but decreased rapidly after that. At longer cooking times this effect disappeared. They concluded that compression wood contents of up to 15% did not adversely affect tear, tensile or burst strengths; but at higher compression wood contents all of these properties would suffer.

DECISION MAKING

The preceding discussion has touched on a number of changes in wood quality which might arise as a result of forest management practices. In a general sense it can be stated that the properties of wood from a managed forest will not be the same as those of wood from a natural forest. These differences will affect the processing, grade recovery, product performance and marketing of the managed resource. Unfortunately, our current level of understanding of the influence of silvicultural treatments on the wood properties of species found in the boreal and Great Lakes-St. Lawrence forests makes it difficult to predict quantitatively what these changes will be. Without specific information on how different silvicultural regimes will influence product properties and value, it is nearly impossible for a forest manager to optimize investments in silviculture. At best, decisions are being made based on volumes of sawlogs and pulpwood. Such plans presume that logs of equal size necessarily have equal quality and value which is, of course, an unrealistic assumption.

For the past several years Forintek Canada Corp. has devoted considerable effort to evaluating quality characteristics in black spruce and jack pine, and while the major emphasis of this work has been on the solid products side of the industry, much of it is also applicable to the pulp and paper sector. Since the growth rates of Canadian forests are slow, it will be decades before sufficient plantation-grown material is available for systematic empirical evaluations of the effects of silvicultural treatments on wood properties.

As a result, Forintek has adopted a theoretical predictive approach to forest crop planning (Kellogg 1989) that utilizes a structural model known as SYLVER. SYLVER, which is a system of computer models that estimates the growth of a stand, converts the stand into products and places a value on the products. This system has recently been described by Mitchell (1988) and Barbour and Kellogg (1989).

Projects for collecting the data needed to run the models used in SYLVER are large and relatively expensive, requiring the cooperation of government agencies, private companies, universities and research institutes like Forintek and the Pulp and Paper Research Institute of Canada (PAPRICAN). The system has been successfully applied to coastal Douglas-fir (Kellogg 1989) and an effort is currently under way by Forintek to initiate task forces in jack pine and lodgepole pine.

The procedure involves sampling trees from selected stands and measuring their basic wood properties. The stands are then harvested and the information is gathered on the costs and efficiencies of converting the logs into products. These data are then employed to create the computer models making up SYLVER, which can be used to make financial assessments of the value of different silvicultural treatments, changes in manufacturing technology or other corporate management decisions.

CONCLUSIONS

The effects of different spacing regimes on wood properties are not altogether clear, and systematic studies for the species in question do not exist. By bringing together data from various species, some tentative conclusions can, however, be drawn. Stem form is likely to suffer from wide spacings, and this will result in a higher proportion of compression wood in the resource. Data on branch size are conflicting, but the most reasonable conclusion is that some increase in branch size can be expected resulting in higher knot volume. Any elevation of knot volume should be subtracted from total stand volume when calculating pulpwood yields. An additional increase in compression wood can be expected in association with larger knots.

Relative density will probably decrease by about five percent. Fibres may be slightly shorter and narrower resulting in proportionally thicker walls, but the extent to which this will influence either pulp and paper or lumber properties is not known. The average microfibril angle of faster-grown trees is likely to be higher than in slower-grown trees but the importance of this is not known. Heartwood content will almost certainly be lower and this is a positive factor for all sectors of the forest products industry.

It is difficult to appreciate how these factors will combine to determine the value of end-products. To evaluate this question it is recommended that computer-based models for predicting end-product value and/or wood quality be produced for eastern Canadian species. While this approach seems expensive, it will undoubtedly be cheaper than continuing to make forest management decisions without a clear understanding of how they will impact on quality and value. It will also be less expensive and faster than following the empirical approach which has been used elsewhere. Finally, it will foster cooperation between the large number of institutions, governments and private organizations that are necessarily involved in such a study.

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A NEW PERSPECTIVE ON SILVICULTURE INVESTMENTS (RETHINKING FRDA PRIORITIES)

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ABSTRACT

The purpose of this paper is to describe the shortcomings of conventional forestry investment criteria and to suggest a more sensible approach to rationing our scarce silviculture funds. The case for this new approach is summarized in the following points, which are given here in the same order they appear in the text:

1. **Timber supply context.** Timber deficits are now being experienced across Canada, especially for quality sawlogs. These deficits can be mitigated to some extent, but only if we reorder our silviculture priorities in a major way.

2. **Traditional investment criteria.** The traditional method of analyzing the net benefits of silviculture spending was originally designed for small, private woodlots in Germany, some 140 years ago. This method is essentially based on short run, economic efficiency concepts. These concepts are both incomplete and biasing, and tend, as a rule, to suggest rates of return which are unnecessarily pessimistic. Neither of these concepts offer relevant methods for judging the merits of managing the large Crown and industrial forests that are already in place.

NOTE: This paper has evolved from a series of presentations over a period of three years. An earlier version was given as an invited lecture sponsored by C.A. Benson and F.J. Anderson at Lakehead University on March 10, 1989. It was included, as well, in a Thunder Bay silviculture workshop on April 18-20, which was organized by Al Willcocks for the Northwestern Ontario Forest Technology Development Unit.

Acknowledgement is due to many people with whom I have discussed the content and presentation. Special thanks is due to Gordon Baskerville and Gordon Weetman for their constructive comments.

3. **Conservation criteria.** Long run concepts of "conservation and wise use" have now been acknowledged almost universally. It is imperative that the forest land manager re-examine the older, short run mindset and give more weight to strategic thinking, which embraces several decades.

4. **The new perspective.** The conventional forester's approach was confined to analysis of the impact of silviculture on timber volumes alone. This is only the initial step in any systematic, benefit-cost calculation. The truly important benefits of silviculture treatments are measured in the following way:
   - moving stands forward in the harvest queue
   - reducing costs of harvesting and processing
   - enhancing value of finished products
   - reducing operating risks.

5. Current silviculture budgets. We now spend close to $1 billion annually on silviculture in Canada. The great majority of this goes to the regeneration of recent clearcuts, while approximately five percent is spent on rehabilitation of land that is not satisfactorily restocked. Less than three cents out of each silviculture dollar is now being directed to the improvement of middle aged stands by precommercial thinning and fertilizing.

6. **Treating middle aged stands.** Application of the expanded investment criteria, as proposed in item 4 above, will generally reveal a much stronger case for the intensive treatment of existing stands of timber. When we compare the base case of natural regeneration with artificial regeneration, and then with subsequent intensive silviculture, the benefits are substantial. These are shown in the next schedule as percentage changes relative to the base case.

The Potential Magnitude of Benefits
from Silviculture Treatments

Type of Benefit	Artificial Regeneration	Intensive Silviculture
Volume gain	+10	+20
Rotation age	-10	-30
Cost reduction	-10	-30
Value increase	+10	+40
Risk reduction	-20	-50

7. **Reasons for improvement.** Intensive forestry will mean additional volume at harvest. The intervention in near mature forests will often boost the stand up to merchantable diameter in 10-20 years less time. This can mean a great deal to companies and local communities faced with curtailment. However, the most impressive gains will likely result from reductions in costs and increased product values. These gains flow from a more attractive species mix, larger and more uniform logs, improved lumber recovery factors, and so on. The cumulative impact on the profit margin is obvious from the right hand column of the above schedule.

8. **Risk management.** The icing on the cake may turn out to be a sharp reduction in operating risks. A well tended timber stand will suffer less from insects and wildlife. More importantly, as a company switched to intensive management it will become less reliant on uncertain fibre supplies from third parties, or on imports and possibly on commercial thinnings or logging residues.

9. **Waiting time.** The conservative land manager has always pointed to the long waiting period between planting and harvest as a reason for favouring natural regeneration. The broader perspective recommended here means that shortening the time between planing and harvesting should be a principal goal of silviculture management. Prompt regeneration with superior genetic stock should reduce the time by 10 percent. An even more helpful reduction comes from intervening in a middle aged stand that would normally take 30-40 years before reaching harvestable diameter. Thinning and fertilizing could reduce the interval to maturity by another 20 percent.

10. **Implications for FRDAs.** Public land managers profess to be keenly interested in getting more value for their money. This analysis indicates that reclaiming the backlog of neglected forest rates low on any objective scale of priorities, except for employment creation. The enhancement of existing stands promises much larger and earlier benefits. These will often become available in one-third to one-half of the time and at a far lower cost than reclaiming NSR. Moreover, improvement of middle age stands is the only approach which promises to mitigate pending curtailments in threatened communities and to open the way for expansion in others. The 1982 FRDA guidelines specified an emphasis on intensive management. The logic is even more persuasive today.

11. **The cost of inertia.** Failure to redirect silviculture funds will cost the taxpayer heavily for unemployment insurance, relocation and retraining, not to mention the social wreckage caused by the collapse of forest-based communities. We must face up to the fact that doing nothing can be very costly.

12. **The missing link.** It will be difficult to achieve the potential set out in this report, apart from a new "Forest Accord." All of the players came together in one of these rare instances of cooperation in the Banff Forestry Conference of 1981. The resulting "Agenda for Action" displayed the kind of long run strategic thinking that needs to be restored. It was a crucial document in setting policy for the FRDA round, which is just finishing.

In short, the fixation of decision makers with the so-called "bottom line" of annual operating statements must be modified. The timber supply context demands that the "top line," namely forest resource, be granted equal time and attention. Short run thinking has already taken its toll.

INTRODUCTION

The Canadian forest industry has entered a new phase characterized by pervasive shortages of sawtimber in nearly every producing region. The more valuable stands of accessible, mature timber are being steadily depleted. Because of the age class structure of the forest, the younger stands are not coming on stream fast enough to prevent a period of short supply. While analyses that recognize forest structure have projected this situation for some time, forest land managers have been slow to respond with adequate budgets and with silviculture regimes designed to address the emerging problem.

One of the principal reasons for the ineffectiveness of forest management is the persistent use of stand silviculture investment criteria, which are both narrow in scope and flawed in their application. Disagreement over these analytical methods is widespread among foresters and academics. Until the controversy is settled, we can hardly blame officials in industry and government for being confused.

The purpose of this paper is to scrutinize the conventional investment criteria and to suggest a more prudent allocation method for silviculture funds. It will be argued that the current preoccupation with forest renewal, and to a lesser extent with rehabilitation of the backlog of neglected cutovers, should be

replaced with a balanced program which includes the treatment of middle aged stands. Millions of hectares of these established forests would respond positively to thinning or other treatments. Yet these receive a negligible share of today's spending. Indeed, the only way to mitigate emerging supply problems is the thoughtful use of intermediate fellings.

The implications of this re-examination will be developed in two directions in this text. In the first instance, it is likely that the federal-provincial Forest Resource Development Agreement (FRDA) agendas contain stand silviculture priorities which are not giving us optimum forest management value for money. Some concrete suggestions will be made on how this might be improved. Secondly, and more importantly, stability is threatened in dozens of forest based communities across Canada, and it would be foolish not to forestall a rupture in timber supply, wherever it is possible to do so, by designing management to the needs of the entire forest rather than to the public desire for renewal alone.

The approach will be to set the stage with a short statement on the timber supply context, to look at traditional forestry economics criteria, and turn thereafter to a more relevant set of calculations. The discussions are deliberately couched in terms understandable to the lay person with no training in economics.

The Supply Context

The timber supply context can be summarized briefly. First, the harvest of softwood in Canada was approximately 175 million m^3 in 1987. In 1986, the aggregate of the 10 provincial annual allowable cuts of softwood was estimated to be 166 million m^3 (Reed 1986). While the basis of that aggregation are of uneven reliability, it is not clear that the total has increased since then. It follows that, for the first time, the combined industry harvest has technically exceeded the softwood allowable cut. Moreover, additions to capacity between 1987 and 1992 will require perhaps an additional 10 million m^3 of softwood fibre.

Meanwhile, a second factor has arisen. The area of mature forest has been shrinking steadily due to planned harvesting and its subsequent replacement with a new forest. At the same time, the application of environmental guidelines and the more recent pattern of setting aside large areas for recreation, wilderness, wildlife habitat and other single uses have caused a further reduction in the productive forest land. The current demands for reservation of old growth, such as the Temagami area in Ontario and the Carmanah Valley in B.C., are just one phase in a lengthening progression of unplanned encroachments on forest licences. This creates a qualitatively different forest management problem on the remaining land base, particularly when the types of forest removed are those which are in shortest supply.

Third, losses of mature timber to insects and wildfire have often been more severe than anticipated when the annual allowable cut (AAC) calculations were made. A further shrinkage of the available supply is becoming apparent as forest inventories are evaluated for economic accessibility. It means little to a firm competing internationally to be told by the provincial forest service that there is plenty of unoccupied timber out there if it is 500 km from the mill; if it is largely unmerchantable for reasons of quality, species mix or product suitability; or if the best of the remaining old growth is about to be designated as wilderness. Raw material cost and quality are paramount when competing internationally.

Amid this gloom over economic wood supply lies an obvious opportunity in expanding markets. Every study of forest product consumption trends points to a buoyant outlook, in volume if not in price. The potential for industrial growth is certainly there, if an economic wood supply can be secured, and that is one of the main reasons for rethinking silviculture priorities. With the evident market potential and the need for sustainable development, the Canadian forest sector should be considering expansion. There are 220 million ha of productive forest land within the provinces. We are now harvesting less than 1 m^3 per ha, on average, from land

which could produce 5 m^3 per ha, provided that forest management is enhanced and the structure of the existing forest is improved.

Given the quality of the land and the growth capacity of our commercial species, it should be feasible to plan for a positive growth scenario, with a minimum softwood production target of 225 million m^3 by the year 2020, which is an increase of only 50 million m^3 over 1987. The increase in harvest in the past 30 years was nearly twice that amount. Beyond that point in time we should think in terms of doubling timber production. Such a vision of the future of forestry is attainable, but it will never be achieved without a new perspective on silviculture investment.

TRADITIONAL FORESTRY INVESTMENT CRITERIA

The standard presentation of forestry investment methods always incorporates a discussion of an analytical model first written up by a German forester named Martin Faustmann (1849). His article adapted an existing mathematical concept to decision making in forest management, and this has since dominated the thinking of the majority of forest economists. In fact, Faustmann made a seminal contribution to capital theory as applied to forestry.

Meanwhile, some 140 years later, most accountants and engineers who do investment feasibility studies have never heard of Faustmann. They simply do the standard corporate financial analysis of new capital spending, which uses the familiar technique of discounting cash flows (both revenues and costs), to arrive at a net present value, and internal rate of return, or a benefit-cost ratio.

These same analysts are employing what is essentially a branch of micro-economics theory or the economics of the firm. It is quite different in application from the analysis appropriate to an entire industry or to the macro-economics of a regional or national economy. The difference is crucially important in that the appropriate approach for the evaluation of a machine in a factory has been applied to a single stand but interpreted as if it were applicable to an entire industry, or in this case, to the whole

forest. Nor does the discounting technique deal with conservation criteria, of which we will speak later.

The selection of forestry investment criteria has spawned considerable literature; almost all of it doggedly pursuing the Faustmann approach and applying it to entire forests. The problem here is the inappropriate use of the legitimate Faustmann idea. Such a **stand** management concept is exactly the right way to discover which of two silvicultural practices, for example, planting or thinning, is the most cost effective way to deliver an additional 20 m^3 on a given hectare. Applying the concept to a small stand and then interpreting and applying the results to the level of the whole forest assumes that <u>all</u> benefits of the treatment are captured on the treated hectare. However, this is a false assumtion that denies the other concept of **forest** management, which relies on the idea that the whole can be greater than the sum of its parts.

The majority of related articles published in North America conclude that silviculture investments pay modest or negative returns. Canadian articles only appear at lengthy intervals and these are pessimistic at best, as demonstrated by Anderson (1979) and Benson (1988). Or they get bogged down, as Manning (1977) and Fraser (1985) do in debates about choosing a discount rate. Occasionally, an author will challenge the conventional approach, particularly on the management of large public forests, as Shepard (1926), Marty (1975), Reed (1985) and Krutilla (1986) do, but these dissident voices tend not to be cited in the academic publications.

However, there does appear to be a new mood of questioning in Canada which can be detected in the calculations of practising field foresters. Many are asking how our competitors in Scandinavia are able to spend double the amount that we do on silviculture and still match us in the market place. Equally important is the fact that the traditional approach has failed to recognize non-timber values in the forest, and in the process of broadening the scope of their analyses, some forest economists have begun to distrust the narrow constraints of economic efficiency as

applied to silviculture spending. Discounting is being seriously questioned as land managers come to rely more and more on conservation principles.

Tracing the pedigree of an influential concept back to its roots can be very helpful in both the classroom and the field. This was in fact done in 1968 by M. Gane in his introduction to an English translation of an earlier exchange in a German periodical (Faustmann 1849). Gane describes how a teacher of forest mathematics, E.F. von Gehren, wrote a two-page memorandum entitled, "On Determination of the Money Value of Bare Forest Land." Two months later, Faustmann challenged his older colleague's statement and offered an alternative method of calculating forest land values in, "Calculation of the Value which Forest Land and Immature Stands Possess for Forestry." Then he went on to discuss optimum rotation length and offered a solution in terms of financial maturity, employing the DCF or discounted cash flow method.

The principal significance for us today, however, was the departure from the Faustmann application of this DCF arithmetic to land valuation, and its application in decision making by the forestry investor. He was the first to apply the discounting method to the ranking of silviculture projects with differing profitabilities. According to Gane, "...it may be safely assumed that DCF originated independently, first in forestry and later on in economics...." This was quite a feat, given that Faustmann was only 37 years old at the time.

Little did these two German foresters know that they were sparking a contentious disagreement that would persist for generations. The land valuation idea was sound when applied to a single stand. It was the extension to forest management decisions which caused the problem. The culprit in this ongoing debate is time; more specifically, the lengthy period needed to grow a crop

of merchantable trees. A.J. Leslie (1976) has aptly described the problem in this penetrating comment:

> "These characteristics of forestry as an economic activity forced foresters to develop a specialized field of applied economics, largely outside main stream economics and concerned primarily with taking time into account as a major input in the evaluation of alternatives and projects in forestry. The fundamental device is to treat time as a capital cost by accumulating the monetary value of inputs and outputs exponentially at some specified or implied rate of compound interest. But the solution to the problem of time as an input created another problem - that of the so-called burden of compound interest - which has troubled forestry ever since."

The preoccupation that Faustmann had with time and compound interest resulted in a single stand case study which is deceptively simple, but at the same time is widely misconstrued in its application to public forest land. The trouble stems from the underlying assumptions, which are never stated explicitly. Much of the confusion should evaporate when these assumptions are identified and compared with the real world.

The Faustmann approach was to start by assuming that a piece of bare ground had just been clearcut. The calculation was based on a Kurhessen acre of approximately 1/4 ha, handled as a single stand. The forestry costs were treated as a long term investment and capitalized at four percent compound interest. The benefits were said to come primarily at the end of a rotation age of 65 years, although minor revenues from periodic thinning might be realized at intervals of 10 years. The single stand stood alone as a profit centre with no associated processing or distribution functions. Finally, the return was measured solely on the basis of the fixed timber volume grown on the land, whether in 65 years, which is the preferred rotation for Faustmann, or in 80 years as von Gehren proposed.

The question is to what extent these assumptions apply in Canada today, especially where public land predominates. The contrasts are unmistakable: (1) Today we begin, not with individual plots of bare ground on which stands will be grown, but

with whole forests that are already in place and in which a few stands are treated annually. (2) The areas are vast and embrace a multiplicity of stand conditions. (3) Silviculture costs are charged against current revenues as an annual cost of staying in business. (4) Benefits of silviculture arise in parts of the forest other than the treated hectares and well before the new plantation matures. (5) The timber land is part of a total provincial or corporate enterprise. (6) Finally, the benefits of silviculture treatments include increased harvest volumes, lower harvesting and processing costs, higher value products, reductions in risk, and possibly more non-timber values. The significant differences in these two sets of assumptions are highlighted in the two columns of Table 1.

It is not intended to denigrate the notable contribution of Faustmann and his contemporary. There are still situations where the DCF evaluation is the only sensible way to gauge the wisdom of a silviculture investment. For example, a larger non-industrial holder of timber land or an integrated company which buys bare land for plantation purposes would be foolish indeed if a calculation of the rate of return were not made by this traditional method. However, when you have a large forest already in place, the correct question is not, "Shall we invest in a new stand on a new clearcut?" Instead, we should be asking, "Are we going to liquidate an entire forest as a valuable capital asset, or live off the annual increment of the forest?" If the answer is to live off the increment, then the appropriate analysis is to discover the silviculture regime that maximizes the annual increment of the whole forest. In projecting the outlook for coming decades, the question becomes, "Are there some attractive opportunities to enhance the value of the forest which is already in place?"

Table 1. A comparison of assumptions underlying the Faustmann Single Stand Model and Canada's Public Land.

	Faustmann	Public Land
1. Starting point	- bare ground	- a forest in place
2. Size of area	- 1/4 ha	- thousands or even hundreds of thousands of ha
3. Treatment of costs	- capitalise, at 4 per cent compounded	- write off costs against current revenue, just as a cost of logging
4. Waiting period for benefits	- to end of rotation age of 65 years	- immediately, if allowable cut effect is possible - within 10-20 years, where stand tending results in cost and revenue advantages
5. Relation to enterprise	- single stand exists alone as profit centre	- forest contributes to profits of a larger economic enterprise
6. Measurement of returns from silviculture action	- fixed volume of timber, which is sold as stumpage	- potential for: - increased volume - lower costs - higher values - reduced risk - also non-timber components are included, in both cost and benefit streams

Having said that, it should also be pointed out that criteria for silvicultural investment in a forest must be tailored to fit other situations as well. For instance, a family-owned corporation with conservative financial objectives may operate differently than a public company with cash flow problems. Or an American company may capitalize some of its regeneration costs according to requirements of their Internal Revenue Service, whereas no similar rules are applicable in Canada. Separate criteria of a macro-economic nature may also be in order for a region with high unemployment and a deficit in its balance of payments. The Faustmann blanket, based on micro-economics of the stand, simply cannot be stretched far enough to cover all of these varied cases of the forest in a macro world.

The controversy over forest management investment methods is still very much alive, and a few citations from recent literature will help to throw further light on the central issues. The first of these is by Robert Marty (1975), who urged that a more comprehensive analysis of forestry opportunities was necessary.

> "There has been a growing awareness among resource economists, and others, that decisions in the public realm are not based solely on considerations of economic efficiency. Financial analysis systems, such as benefit-cost analysis, do not provide enough information on other relevant characteristics of alternatives. Financial analysis alone is both incomplete and biasing, in that non-financial characteristics of alternatives are either ignored entirely or treated only with regard to their effects on economic welfare. It's time for analysts to broaden their point of view."

A year later, Paul Samuelson (1976) discussed forest economics in a University of Washington symposium, presenting a modern version of the traditional model. In turn, John Krutilla (1986) commented perceptively on the Samuelson statement. The following quote from Krutilla underlines the limitations of the Faustmann framework for addressing present day problems.

> "Samuelson, of course, didn't imply that his paper was original, or that it was in some sense an essential theoretical advance over Faustmann's original contribution. Indeed, he even disavowed that it was

> relevant for multiple-use forestland management. Essentially what Samuelson did was to provide a very elegant modern restatement of Faustmann's model and to demonstrate that it was consistent with the neoclassical theory of efficient resource allocation. I will be asserting that this model, which represents the unwitting mindset that supports some forest economic policy studies of National Forest Management, is not only largely irrelevant, but conducive to a great deal of mischief."

Krutilla went on to state that the classical model was indeed valid in certain situations, but he insisted correctly that multiple-use and multiple stand (i.e., forest) management of public land were fundamentally different in character from Faustmann's small, privately-owned piece of bare ground.

Most Canadian authors also lean toward the earlier German formulation. G.H. Manning (1976) published an article in which he argues that the choice of the discount rate is critical in evaluating intensive forestry opportunities in British Columbia's public forests. He concludes that such investments are unlikely to be made with "market derived" discount rates and that another calculation based on a "social discount rate" might be worth trying in British Columbia. G. Alex Fraser (1985) followed a similar line of reasoning and reached pessimistic conclusions as well. Fraser suggests that alternative methods might be explored, such as the allowable cut effect, but he declares that it has questionable validity. Neither of these authors appears to grasp the significance of moving older stands forward in the harvest queue.

The classical approach was also favoured in a lengthy Forestry Chronicle piece by C.A. Benson (1988) entitled, "A Need for Extensive Forest Management." He advises against intensive forestry in the following passage:

> Instead of trying to emulate the intensive management strategies of the Scandinavians and Americans, it may be to our competitive advantage to consider extensively managing our larger, but less productive forests, to produce a second forest at the lowest regeneration cost possible.

Admittedly, perspective is difficult to maintain in the face of these seemingly contradictory positions. Some have found that another pioneering work by Talbot Page (1976) is helpful. In a book published by Resources for the Future, Page contrasts two approaches to raw material investment strategy. The first is economic efficiency, which in forestry means the technique of corporate financial analysis with roots in Faustmann. The second is conservation theory with its emphasis on intergenerational values. Each has a legitimate and distinct role to play. In Page's words:

> "The conservation criterion, or at least, its more ordinary manifestation as a sustainable yield criterion, is often criticized on the grounds that it does not maximize the present value of the yield's benefits. This reasoning is surely wrong. It is no more appropriate to conclude that the sustainable yield criterion is invalid because it does not satisfy the present value criterion than it is appropriate to conclude that the present value criterion is invalid because it does not satisfy the sustainable yield criterion. One cannot use one criterion to bludgeon another. They are on the same logical level. The most one can say at this point is that the two criteria conflict; they imply different states of the world."

The real challenge is to synthesize the two in a system which can be tested and applied in real life situations. This is worth pursuing a step further. In Canada's vast provincial forests, as well as in larger industrial holdings, the policy decision has already been made to maintain the forest capital. On publicly owned lands, it is considered totally unacceptable to harvest land without providing for prompt regeneration. Regeneration is an annual cost just like logging, and is written off against the operating revenue in the same year. This position is based on a conservation ethic that places great emphasis on community stability and the importance of ensuring a means of livelihood for our children. Calculation of rates of return on individual stand regeneration is irrelevant in public forests. The Faustmann construct has nothing whatsoever to contribute to this decision to conserve an entire forest while harvesting some stands.

However, once the decision has been made to regenerate, the Canadian forester is entitled to argue for the largest budget consistent with maximizing the forest increment which can be harvested. He will marshal all of the micro, macro and conservation arguments available. When the usually meagre funds are eventually committed, efficiency criteria come into play immediately, as one of the rational methods of allocating scarce funds. It matters little whether the discount rate is four percent or eight percent, the priority ranking of silviculture options for various stands in a forest will not differ importantly. Silviculture enters the picture in two ways. First, forest level analysis will indicate what changes in stand yield curves are required to achieve a target level of harvest. Second, the needed change in stand yield curves will determine what combination of silviculture treatments will achieve the change most cost effectively.

But that is still not the end of the rationing exercise. The dynamic process of policy making may, and often will override the economic efficiency ranking. To illustrate, society may impose requirements for the preservation and management of recreation, wildlife and other forest-based values. This in turn will either reduce the timber available on the remaining forest, or increase the silviculture necessary to maintain the same harvest from a smaller area. In another situation, economic efficiency may favour spending in one region over another, regardless of the demonstrated biological and economic rationale. But we cannot deny to elected political representatives their right to decide that a low site in one region is entitled to silviculture treatment just as much as high site land in another. The politician is elected, after all, and is presumed to speak on behalf of society at large.

This important point deserves to be underlined. Forest economists need to be reminded regularly that they may not be the first to be consulted about spending on forest management, and it is unlikely they will be the last. The next section suggests how

they might become a great deal more persuasive in silviculture policy formulation and program planning.

A New Perspective

There are two interesting aspects worth noting before describing this fresh approach. The first is that the public and the forest community have a certain fixation with regeneration following clearcutting. It does not seem to matter in professional quarters whether this is accomplished by natural or artificial methods, although the preference seems weighted toward planting. Rehabilitation of the backlog of neglected cutover forest land often ranks second in importance. Intensive treatments of stands over 20 years of age, whether plantation or natural, have received little attention in forest management planning and only token budgets to date. The approximate division of silviculture expenditures in the mid-1980s can be inferred from a Kuhnke report (1989) which has just been released. The shares are estimated as follows:

Regeneration and related juvenile tending	92 percent
NSR rehabilitation	5 percent
Stand enhancement	3 percent

It appears that less than 25,000 ha of middle age stands were thinned or fertilized in 1985-86, the latest year for which we have national data. The absence of stand enhancement programs results from a poverty of thought in forest management planning.

It seems fair to observe that there has been too little conscious allocation of silviculture budgets in accordance with systematic forest management analysis. Least-cost rules of thumb determine whether natural regeneration is selected over artificial, without much reference to its impact on ultimate crop value and on forest level productivity. The reason most often given is that it is such a long time before the resulting crop is sold that cost minimization is the proper guide. Another simplistic solution holds that the rehabilitation of NSR is recommended only on good and medium sites, and without reference to distance from producing

mills. This choice is made with no empirical evidence, even though the need to reduce high transport costs might suggest we also treat low site when it is close to the mill. Moreover, none of these rules of thumb are applied in the context of forest-level wood supply analysis.

The second aspect to highlight is the concentration of many of our conservative foresters on volume increments, to the virtual disregard of the potential for cost reductions, value enhancement, and lessened operational risk. Intensive forestry can also be used to mitigate sawlog and other fibre shortages by making suitable material available sooner. The results can be critically important in those forest-based communities threatened with curtailment by impending timber deficits.

The range of benefits due to intensive silviculture activities are itemized in Table 2 for simplicity of presentation. We have yet to see a systematic discussion of the entire potential in a Canadian study. Published papers tend to confine analysis to volume increments shown here as item 1. These are customarily multiplied by projected stumpage values to provide the only impact on the revenue side of benefit-cost calculations. The other sets of benefits listed in Table 2 are generally ignored. There is some recognition of the fact that intensive treatments might bring an under-mature crop to harvestable diameter much sooner, for example, in New Brunswick. Comprehensive case studies are still not being written up.

Table 2. Benefits from intensive forest management.

1. Volume increase

2. Shorter time to forest operability and sawlog diameters

3. Cost reductions

   a. shorten hauling distance
      - by treating land near the mill

   b. produce larger more uniform logs
      - for logging cost savings
      - for lower processing costs

   c. protection costs reduced
      - forest is harvested at younger age
      - less natural mortality

4. Value gains

   a. species mix improves

   b. lumber recovery factor raised

   c. grade and dimensions mix enhanced

   d. residual chip values increased

5. Risk reduction

   a. insect and fire losses

   b. less reliance on open market
      - for logs
      - for pulp chips

   c. less risk of curtailment from timber shortage

Of equal significance are the potential gains in competitive vigour by means of operating cost reductions and increased product values. Average hauling distances can be shortened by directing intensive treatments to areas near manufacturing facilities, thereby reflecting the wisdom in the old proposition, "Let's bring the forest back to the mill." Then, by treating those stands that will respond to thinning and fertilizing, we can produce fewer logs, which are larger and more uniform. This will result in cost savings in both harvesting and processing. In addition, a well tended stand will likely require less expenditure on protection against insects and fire. Unfortunately, the Faustmann stand analysis mentality restricts attention to line 1 volume increments.

The value list shown in Table 2 could be even more impressive. The first of these is the expected shift in species, away from hardwoods and toward spruce and pine. This will result from prompt planting, adequate brushing, conifer releasing and intermediate felling. The better quality, larger logs will provide higher lumber recovery factors, a more profitable grade and dimension mix, plus a richer diet of residual chips and roundwood for use by the pulp and paper sector. More of this will happen and the treated stands will be ready 10-20 years sooner. Some interesting documentation is now being assembled such as that by the Sterling Wood Group in B.C. (1988), which reveals "... a dramatic increase in stem value effected by a diameter increase between 15 cm and 25 cm." We are finally getting the empirical data which has been relatively scarce to date.

Then, as an added bonus, a firm can expect a progressive reduction in operating risks on three counts: lower probability of loss from insects and fire, less reliance on open market purchases or imports of logs and pulp chips, and a reduced likelihood of curtailment from timber shortages. It will also be asked how long a company will have to wait to experience a risk abatement. Certainly not till the end of an 80-100 year rotation age, as the conventional stand analysis maintains. Corporate managers are accustomed to assessing the impact of risk on the

entire company, and are quick to identify the benefits of reducing such handicaps to the earning potential of an enterprise.

A notional approach to quantifying these benefits for a company is shown in Table 3, which illustrates the kind of percentage changes a firm might anticipate as it moves from the base of natural regeneration, through artificial regeneration and then into intensive forestry. Published data for Prince George has been adapted from the B.C. Ministry of Forests (1988) for illustrative purpose. The volume gain and the earlier harvest already referred to will often yield an immediate increase in the annual allowable cut, provided that the reservoir of mature timber has not been taken below a danger level. Silviculture interventions will open options for treatment of other stands immediately. Cost reductions in logging and processing in the range of 30 percent may begin to accrue in as short a time as 20 years. Value added increases of 40 percent should be realizable within the same time frame. The impact on operating margins will likely be modest at first but will accumulate, steadily. The icing on the cake may turn out to be lessened risk for those companies with an insecure timber supply.

The benefits of intensive forest management can also be calculated for provincial policy makers who are more interested in the net impact on the public treasury, which results from: stumpage collection; other tax revenue generation; the chain of secondary effects involving less welfare; and unemployment costs, as well as the stimulation flowing from increased economic development. Also important for strategic planning is the prospect of lessening the tension over reallocating forest land to preservation and recreation categories. This positive result could be realized where there is a potential to increase the total available supply of industrial timber, thereby increasing the size of the pie rather than simply quarrelling over the existing one. It ceased to be a zero sum game.

Table 3. Comparison of silviculture options for the Prince George Region in B.C.

		Natural Regeneration	Artificial Regeneration	Intensive Silviculture
	Costs ($ per ha)			
1.	Site preparation	150	200	200
2.	Planting	--	500	500
3.	Brush, weed	500	300	300
4.	Juvenile space	500	400	400
		$1,150	$1,400	$1,400
5.	Pre-commercial thinning			500
6.	Fertilizing			200
				$2,100
	Impact			
		Base Case	**% Change**	**% Change**
1.	Volume gain	100	+10	+20
2.	Earlier harvest	100	-10	-30
3.	Cost reduction	100	-10	-30
4.	Value lift	100	+10	+40
5.	Risk reduction	100	-20	-50

SOURCE: Cost data based in part on B.C. Ministry of Forests data for 1986-87.

Impact estimates based on advice from Ministry and operating companies.

What has been titled "A New Perspective on Forest Management Investments" may not be so new to some readers. Some time ago two Swedish foresters, Fries and Hagner (1970), made a rather similar presentation to an American Pulpwood Association symposium, and a growing number of Canadian forest managers have begun to do this arithmetic more recently. Unfortunately, there are far too many chief foresters, senior officials, and company directors who are not yet aware of the potential described above. Moreover, there is still a habit among some academics to emphasize stand volume

increments rather than forest dynamics during classroom instruction.

One of our problems in Canada is that we have tried to mimic the current approach of European silviculture practice. While it may appear to be stand related, it is based on a solid framework of total forest analysis. In other words, forest management is the reference for stand management. It is likely that a high proportion of foresters have had this forest perspective for some time. In contrast, forest economists have remained disconnected from real forest practice. In spite of this handicap, they have been prominent in advising government.

Before moving on to the implication of this discussion for FRDA priorities, it may help to restate a couple of basic propositions. First, economic efficiency criteria represent a valuable tool for foresters in certain situations. Second, micro-economic analysis is essentially concerned with contemporary calculations of the short term interests of the firm, and in a highly local situation. It was never intended to serve as the sole guide for decision makers who face public issues involving long periods of time and extremely large areas. Third, conservation criteria are a vital part of the thinking of senior officials and elected politicians. They have a fundamental responsibility to perceive the intergenerational impact of public policies.

In short, foresters and economists will have to learn to distinguish the following contrasting concepts and to apply them to forest management without bias.

1. Economic efficiency criteria and conservation criteria.
2. The micro-economics of the firm, and the macro-economics of public land management.
3. Net present value and intergenerational value.
4. Long run and short run effects.
5. Direct and indirect effects.

Implications for FRDAs

The existing FRDA agreements reflect widely differing sets of priorities, as they should. Each province has tried to use these funds wisely and in a manner consistent with their individual social and economic policies. However, circumstances have changed importantly since 1982. For example, Quebec, Saskatchewan and British Columbia have now followed the lead of Alberta, where industry has long been required to pay for the majority of forest regeneration costs on Crown land. The pressure on the federal government to contribute to forest renewal will be greatly reduced. In fact, a somewhat better argument can probably be made now for the application of federal funds to rehabilitating the backlog of NSR forest land because industry has not been required as a rule to shoulder this task.

As indicated above, a technically more persuasive case can be made in support of federal participation in silviculture programs related to intermediate fellings, particularly in those regions where industrial curtailment has already begun or is expected within a decade. The costs of treating these stands will almost certainly be less than the welfare, unemployment insurance, relocation and retraining burdens associated with the collapse of forest-based communities. At the same time, we should be aware that commercial thinning is a standard procedure in other countries and that we may find it profitable here as well.

Two other silviculture programs are also crying for more attention. The first is on Indian reserves and those adjacent lands where provincial forests might be made available to local bands under long term, area-based licences such as those which exist in British Columbia and Saskatchewan. The second is on small private forests, where the present cost-shared programs may have to be expanded considerably in some regions of Canada in order to provide a foundation for stable economic growth.

To illustrate the possible shifts in FRDA emphasis, we can turn again to British Columbia. Table 4 provides approximate figures in column 1 for the five years ending March 31, 1990. A

suggested new profile is given in column 2, anticipating the kind of analysis that recognizes forest dynamics. What is indicated here is that the dominant NSR program should be dropped from first place to second, because much of the good and medium sites closer to the mills has already been treated. Intensive treatments like precommercial thinning and fertilizing would move to the top priority.

Management of small private and Indian forests would also move up dramatically, along with a good portion of the extension and technology transfer items. The rationale for this is admittedly based on social goals and longer term economic objectives, rather than return on investment in the short run. Column 2 is put forward for discussion purposes and is not intended as a precise agenda.

The first two lines on Table 4 also require comment. It is mandatory that every FRDA agreement be based on a strategic plan with explicit treatment of forest dynamics over at least an 80-year time horizon. Such a strategy will stipulate future raw material availability in terms of species, volumes, log size and quality, and it will specify the forest management regime which is necessary and sufficient to achieve these goals. The No. 2 guideline in A Framework for Forest Renewal, adopted by the Canadian Forestry Service in 1982, stipulated a long term plan of at least 20 years duration, a period now regarded as too short. Dealing with program priorities, the fourth guideline reads as follows:

> "Emphasis on Intensive Forestry. Federal funds will be applied wherever possible to intensive timber stand improvement. Provinces and industry will carry the major responsibility for basic forestry, namely prompt regeneration."

Table 4. FRDA agendas for British Columbia (million $).

		Estimated 1985-90	Tentative 1990-95
1.	Strategic Plan	-	1
2.	R & D	20	40
3.	Intensive Forestry	70	150
4.	NSR backlog	180	50
5.	Small private forests	2	8
6.	Indian forests	2	7
7.	Extension/Technology Transfer	20	20
8.	Industry/Trade/ Development	2	2
9.	Economic analysis	2	2
10.	Communications, etc.	2	2
		300	300

NOTE: All numbers approximate.
The eventual allocation should of course be soundly based on coherent timber supply analysis and real forecasts of wood availability. The No. 1 item calls for a strategic plan that would serve as the essential foundation for a new FRDA.

This is a statement of program priority, and by inference an indication of the division of funding responsibilities. The first two items on Table 4 are noted here to underline the critical importance of strategic thinking, which is far from adequate in most provinces. It is very difficult to justify a new FRDA agreement before a comprehensive plan has been tabled, including timber and non-timber objectives, as well as specific program components. The federal government can hardly be expected to embark on a forest management journey with any province without first receiving growth goal targets, a logical set of priorities, and an action plan incorporating budgets and time schedules.

Line 2 on the B.C. FRDA agenda calls for a doubling of forestry research and development in the next round. Silviculture research still lags badly, and we might properly expand the definition to include timber inventory analysis and site classification. We still lack yield tables for managed and natural stands, as well as site classification. Without this information it is impossible to forecast wood supply. Then we can proceed to identify stands which would respond positively to thinning and fertilizing.

Much of what is indicated above for B.C. is also true in other provinces. There should be a rigorous scrutiny of priorities, R & D in particular, in order to improve substantially on forest management performance. We are not making efficient use of existing budgets. For example, according to Kuhnke (1989), the average success rates for spruce plantations are only 65 percent. This is not acceptable, given the fact that spruce is the most important species harvested in Canada.

EPILOGUE

This paper argues for a new perspective on silviculture options by policy makers, one which stands back from the individual stand and focuses on the dynamics of a large forest. The need for this shift in viewpoint is underscored by Schmookler (1984) in the following quotation:

> "In an age of specialized analysis . . . the study of forests is considered best pursued as the study of particular trees. Even as pictures from satellites open our eyes to sweeping vistas, our world view tends to be myopically mired in the magnifying-glass stage. The parts are delineated in excruciating detail, whereas the whole is left for some invisible hand to assemble or is regarded as no more than the sum of its parts."

Having said this, it would be quite unfair to leave the impression that no one in Canada is doing forest level simulation to design management. New Brunswick is already very good at this, and so are a number of companies. Some other managers are progressing rapidly in this regard. The point is that policy makers and many who advise them still fail to grasp the significance of managing the forest, in contrast to simply planting cutovers.

Finally, it is sincerely hoped that this intervention in forest economics will not lead to an undisciplined wrangle in professional journals. I offer it instead as a positive challenge to renew the search for a new set of silviculture prescriptions.

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THE EFFECTIVE USE OF BENEFIT-COST ANALYSIS IN FOREST MANAGEMENT

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ABSTRACT

This paper outlines the rationale and use of benefit-cost analysis in forest management. Often, the broad objective of forest management is to generate the maximum benefit for society or a private firm, depending on the analyst's perspective. However, management unit objectives are expressed as physical output levels. Benefit-cost analysis provides standardized techniques for determining the net level of social welfare generated. This paper outlines a process whereby superior management regimes can be identified in a stand level benefit-cost analysis and inserted into a forest level simulation model. Since the forest-wide benefits cannot be fully appraised on a single-stand basis, the manager must test the selected regimes on a forest level basis. Repeating the process of evaluating management at the forest level, improving it by adjusting the stand level regimes and then re-evaluating the new set of practices at the forest level will lead to the identification of a sound and economically superior management strategy.

INTRODUCTION

Benefit-cost analysis is the name for a set of techniques which enable an analyst to evaluate the economic attractiveness of one or more projects. It is intended to enable an agency to identify the projects that will create the largest benefit (Anon. 1976, Mishan 1973). Government analysts may evaluate whether society is better off if one particular project is undertaken, or they may select one or more of the most socially beneficial

projects from a number of alternatives. Private analysts would answer analogous questions from the perspective of the firm.

The economic characteristics of a project can be evaluated using several somewhat different rationales, thus there have emerged at least several benefit-cost measures. Furthermore, since these measures compare project costs and benefits somewhat differently, the order in which a given set of projects is ranked may depend on which statistic is used, especially when the project is complex.

This paper will explore how benefit-cost analysis (BCA) can be used in forest management planning. To do this, it is first necessary to look at the objectives of management planning and the indicators used to assess the performance of a plan. In the course of the discussion, it will become evident how BCA can best be used.

The reader should be aware that the conclusions reached below will not be in the form of a set of rules delineating when BCA should be used in one way or another; this is so for two reasons. Firstly, it is not feasible to encompass every possible situation in a simple set of rules; indeed, it may not be possible no matter how complex one is willing to make the set of rules. Secondly, since the different measures developed evaluate different characteristics of a project, it follows that different information is provided by each measure (see also Anon. 1976). It is suggested that more than one measure should be examined for each project, even if the analyst subsequently decides that the specific circumstances give one yardstick more relevance than another.

THE PROCESS OF FOREST MANAGEMENT PLANNING

To be effective, forest management planning must be conducted jointly at two levels: the forest level and the stand level. A forest is thought of as being the aggregation of stands which is managed to yield a flow of benefits, usually on an annual basis, consistent with the objectives of the owner. This definition includes management units and working circles. The important forest-level attributes include age class structure, the quantity

of growing stock, harvest sustainability under different harvest strategies, the mix of species throughout the forest, and the distribution of age classes and site types throughout the forest (Baskerville 1978).

The stand level is where activities are undertaken to implement plans. A typical stand level unit may be an individual stand, or more likely, a cut block or treatment block. Influential stand level characteristics include the yield curve that the stand is following, its age, merchantability, species composition, distance to mill, and site type.

Management objectives are set and monitored at the forest level but they are achieved through stand level activities. The specific objectives will depend on the particular circumstances. A forest products company will usually have a forest-wide objective of providing a sufficient and sustainable flow of timber, possessing various characteristics, at a reasonable cost. In contrast, typical Crown objectives are to provide a satisfactory, continuous supply of benefits, including timber, wildlife, and recreation for the overall good of the province's citizens. Note, too, that the impact of stand level activities on forest level indicators is not apparent from the stand level, whereas the stand level characteristics are not discernible at the forest level. To see the entire picture, management must proceed at both levels.

Thus, management planning should be an iterative process; the manager begins at the forest level and assesses whether natural regeneration will be sufficient for the forest to be able to meet the objectives set for it. It may turn out that no treatment is required; however, if the desired harvest level cannot be sustained without assistance, then some set of management actions must be selected and undertaken. This may simply be a continuation of the current treatment practice. Once a set of actions is proposed, foresters must go back to the forest level and assess whether they will produce the intended effects without causing undesirable side-effects. Further adjustments to the set activity may be required.

This process of moving between the two levels can be continued at least until the problem is corrected.

The forester need not stop here. It may be possible to improve the solution. For example, there may be a cheaper way to meet the sustainable target. For each set of circumstances, there will be an optimal set of activities, and it would be desirable to closely approach the optimum. This is inherently difficult to do because no single-dimension yardstick can fully assess multi-dimension solutions.

The forest level analysis can be conducted using a simulation model such as FORMAN (Wang et al. 1987) or linear programming. If FORMAN is used, the forest is aggregated into classes of similar stands, which are described in a class file and are linked to specific yield curves: one for the present stand; another for the cutover area to follow if no treatment is performed; and a third that will be followed if management is undertaken. The set of management activities is expressed as harvesting, planting, and thinning levels. Their effects are simulated through the behaviour of the yield curves that the cutover area ends up following.

If an emerging problem is detected and some management is required to prevent it, then the forester can identify which combinations of forest classes and treatments are likely to prevent it, and specify that those treatments will be undertaken on those forest classes. Although the new set of management regimes may appear to correct the problem, FORMAN should be run to examine the ensuing outcome. If it is unsatisfactory, adjustment of the activity levels and regime design is required. This process should continue until the problem is prevented.

MEASURING THE SUCCESS OF FOREST MANAGEMENT

Now that a process for management planning has been outlined, it is appropriate to look more closely at the various objectives of forest management, and to describe how a plan or plan component might be evaluated. Table 1 lists some common forest-level

quantities that are often part of the objectives. Each is a forest attribute that can be altered through management.

Table 1. Forest level objectives.

Timber Production	-	Quantity
	-	Sustainability
	-	Species Mix
	-	Size and Quality
	-	Regulate Age Class Structure
Cost of Treatments	-	Acceptable
Wildlife Habitat Production	-	Quantity
	-	Sustainability
Production of Recreation Opportunities	-	Quantity
	-	Sustainability

In some cases, a single number will indicate how well one particular objective is met (e.g., the number of cubic metres of wood obtainable in each period over the next hundred years measures the harvest quantity). In contrast, the degree to which objectives such as sustainability are achieved is more difficult to quantify.

However, it is important to weigh one objective against the others. One approach is to derive a composite measure that will take each of these objectives into account. In this way, the effectiveness of the entire management plan can be assessed. As the reader can see, it is difficult to evaluate management plan performance using a single index.

A manager will also wish to evaluate the contribution of a particular stand level regime to the attainment of forest level objectives. This calculation is complex, too. Qualities such as sustainability and age class structure are meaningless at the stand level. The annual forest-wide cost of forest management is often far more important than the cost per hectare of some management

regimes. An additional difficulty is that the interactions between stands in the forest will not be captured in a stand level analysis.

USE OF BENEFIT-COST ANALYSIS

It is now clear why benefit-cost analysis can play a useful role in forest management. None of the forest level objectives are easily related to the social or private benefit created. Secondly, BCA provides a single dimension yardstick for evaluating and comparing varying forest-wide programs or individual plan components. Using the measuring rod of value, a consistent and meaningful assessment can be made.

There are several benefit-cost criteria which are widely used: present net worth (also net present value); the benefit-cost ratio; and the internal rate of return. Present net worth (PNW) is the sum of discounted benefits minus the sum of discounted costs, as shown in equation (1); and the benefit-cost ratio (BCR) is the sum of discounted benefits divided by the sum of discounted costs (equation 2). The third criterion, the internal rate of return (IRR) is the discount rate, which sets the value of the PNW in equation (1) equal to zero. A discussion of the analysis procedure can be found in Anon. (1976) and Nautiyal (1988).

(1) PNW = Total discounted benefits - total discounted costs

(2) BCR = Total discounted benefits/total discounted costs

A project with a PNW of zero will break even and the project with the largest PNW is the most favourable. A BCR of one (1.00) is obtained if a project breaks even and the largest BCR is desirable. A project will be economically desirable if the IRR exceeds the rate of return earned on the most profitable alternative investment. The highest IRR is preferred.

The criteria reflect preferences for more benefits, other things being equal, and for the receipt of benefits as soon as possible, other things being equal. As the equations show, PNW expresses the size of the net benefit obtained, whereas BCR expresses the effectiveness of a cost dollar at producing benefits.

The IRR is the compound rate of value growth during a project (Mishan 1973, Nautiyal 1988). It is difficult to see how this contributes insight that the BCR does not.

The oft-cited advantage of the IRR is that the discount rate need not be selected. This would be an important advantage if it were completely true; but it isn't, since a project is only worthwhile if the IRR exceeds the rate of return that could be earned in an alternative investment. Thus, judging the feasibility of a project involves selecting a discount rate.

PNW and BCR can both be used to evaluate a forest-wide program or a stand level management regime. However, the IRR is difficult to justify in most realistic forest-wide circumstances. The reason is that the IRR only identifies the best projects when the entire net proceeds from an investment can be re-invested to earn the same rate of return. This implies that projects can be repeated in a proportionally expanded form. Since the forest landbase is limited, this condition cannot hold and the IRR is not appropriate. For these reasons, it will not be discussed further.

When the BCR is calculated, care must be taken to ensure that negative side-effects are treated consistently (Anon. 1976). Some analysts treat all negative effects as costs and others view negative outputs as negative benefits. The choice made affects the value of the BCR. Inconsistent procedures can render the BCR values erroneous. Such problems arise most frequently when dissimilar projects are compared (e.g., health care and forest management), rather than projects such as different forest management regimes.

The PNW and BCR measure different economic aspects of a project and do not provide the same information. The PNW value indicates nothing about the efficiency of the investment, whereas the BCR does not describe the size of the project's returns. This is why the two criteria will not necessarily rank a given set of projects in the same order.

A frequent question is, "Which indicator is best?" Virtually unanimous support is found for the use of PNW as a ranking criterion when an individual project can be selected without restriction (Nautiyal 1988, Clutter et al. 1983, Anon. 1976, Mishan 1973, Hirshleifer 1970). The issue is more complicated in other cases. A simple example will demonstrate this. Suppose two projects are being compared. The associated discounted costs, benefits, and BCA statistics are shown in Table 2.

Table 2. A hypothetical comparison of seeding and planting.

Project	Cost ($/ha)	Benefit ($/ha)	PNW ($/ha)	BCR
Planting	400	700	300	1.75
Seeding	50	150	100	3.00

If the budget is unlimited, and say 10 hectares are eligible for treatment, then it would be best to plant all 10 hectares. The net return would equal $3,000, three times as much as seeding would produce. However, if there is a $600 budget, the greatest net benefit is obtained by maximizing the average efficiency of the investment. The optimum action is to seed the entire area and generate a net gain of $1,000 (the $1,500 portion of the budget that is not spent should also be included). In contrast, planting 1.5 hectares will yield a gain of $450.

With a $2,000 budget, planting four hectares and seeding six hectares will be optimum. This optimal solution could be derived using linear programming (LP) techniques, but it cannot be deduced by looking at just one indicator. The budget and the available area jointly affect the decision. When LP is unavailable, the second best solution can be obtained by adopting the BCR as the decision criterion. The calculations show that seeding the entire

area yields a net benefit of $1,000. Including the leftover budget, the entire net benefit is $2,500. In contrast, five hectares could be seeded to produce a total benefit of $1,500. The BCR has correctly identified the superior solution.

This example indicates that there is no single rule which can be applied to all situations, and that some creativity should be exercised. It appears as though the use of BCR will lead to the best selection of projects when there are constraints on management and when a simulation model is used to select the management program. Willcocks et al. (1989) also demonstrate this, using more realistic case studies. Knowing both the PNW and the BCR is useful and therefore, it is recommended that both be calculated and examined.

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SITE-SPECIFIC SILVICULTURE: WHAT'S THE RIGHT CONTEXT?

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INTRODUCTION

My subtitle is, "Are you doing your homework?" My aim is to give a sort of pep talk, or in other words, some encouragement for you to take a specific part of forest management very seriously. The presentation is structured around a set of premises, principles, questions, and statements around which the theme indicated in the title will be delivered.

1. Forest management is your business and charge.

I address this paper mainly to forest managers. Let us begin by looking at what forest management is. There are many definitions - many good ones, and some useless ones. Surely you have your own favourite. My favourite is: making forest plans, and implementing them. Adaptive forest management is doing that rigorously, looking at implementation success carefully, and replanning with new knowledge (for more on this, see Baskerville 1985, 1986).

2. To be a forest manager, you must be planner.

You may claim to be in the business of forest management. Are you a forest planner; are you mainly a plan implementer; or, are you neither (e.g., because there is no plan that is connected to the forest, or because you simply take orders to do silviculture)? Or are you both a forest planner and a plan implementer? Then you really are a forest manager, and are well-placed to make a difference (in fact, I would like to have your job)! A manager makes plans, and implements them. The connections between plans

and implementation (in both directions) are crucial. We've got TMPs (Timber Management Plans according to the OMNR process) now, we've got lots of silvicultural activity now, but do we have the two-way connections?

3. Planning is foresight that matches means with ends.

For Ontario foresters, planning is partly doing TMP well, but it's much more - it's all your forethought as a forest manager. Thus, planning is forecasting objectives (what we want) and strategies (how to get there). We can illuminate the concepts of ends and means with a few questions:

end = objectives = where should my forest go?
= what kinds of benefit flows do we want?
= what kinds of futures are desirable?

means = strategies = where could my forest go?
= what kinds of benefit flows do we want?
= what kinds of futures are possible?

The forest manager, as a planner, needs to have a good understanding of both of these. Forest managers sometimes have the authority to set ends, but often do not. However, the forest manager does have a duty as a forester to know the means and be technically competent in forecasting forest response to silvicultural intervention. During panel discussions at the 1988 symposium on "Forest Investment: A Critical Look," sponsored by the Ontario Forest Research Committee, G. Baskerville said that the single-most important role of the forester, which must be competently discharged if foresters are to retain any credibility as forest managers, is the role of forecasting forest responses to management actions! If you can't anticipate your future forest well, just watch your grip on responsibility for forest management slip away! You've got to be the competent symphony conductor. You may know the score inside out, you may know when to cue the violins and the cellos, you may know how to play several of the symphony instruments yourself, you may know the sound you want from each section, everything may look good - so you rehearse (plan), and

then execute (perform, implement) - but if you can't pull it together to give the paying customers what they want and keep a "sustainable" orchestra over the long term, you won't last long!

How many of you, as forest managers or forest management helpers, have a vision, even a cloudy one, of both means and ends for the forests under your care? How many of you feel comfortable with your vision of either one? Do you ever have sleepless nights because of insufficient funds for forest management? Or over the lack of good technical tools? Or due to the lack of control over funds for your work? If you have any, they should be over a lack of solid analyses of how forests respond to coordinated sets of local silvicultural intervention, and what are the best ways to spend limited funds.

4. Planning perspectives: think global, act local; think long-term, act now.

For forest management, "think global, act local" means act at the stand level (or treatment unit level) to contribute to desired forest structure and benefit flows in 25 (or 50, or 75) years. These maxims are universal. For example, pension plans make you pay now for dollars later. As another example, in climate change we have a global problem, but we need to implement local to national solutions.

It is crucial to coordinate and craftily construct the links between the global and the local, the far off and the now. Referring to the examples above, with pensions, group plans ought to make more pension dollars available than if you save alone. With climate change, what difference does it make if I stop driving a car, or switch from gas to solar heat in my house, and no-one else does? Or if Canada reduces its carbon-dioxide emissions and the rest of the world does not? To sum up, planning is applying these principle, and focusing on the links.

5. Planning is vital. Why?

Why is it so important to connect stands, or groups of stands, to forests, and now with the future (i.e., to provide appropriate spatial and temporal contexts)? Here are three good reasons:

(a) impacts of silvicultural treatments are cumulative - if a stand is treated now, its course is set for decades (if not a whole rotation), and the contributions it can make to forest-level objectives at any future time is largely predicated on the treatment given now (this also applies to treatments foregone!);

(b) investments are sunk - you can't easily shift them around; if the wrong species gets planted (for whatever reason), you can't go pull the seedlings out and get your money back; and

(c) money is tight - as discussed elsewhere in this volume, you should get it right the first time. Much of the game in "getting it right" is knowing that it's right for helping meet forest objectives.

As a forest manager, you cannot afford not to plan. As a society, we cannot afford for you forest managers not to plan, or to do it incompetently!

6. We all know your real forest management context is a zoo of conflicting objectives, debilitating constraints, huge uncertainties, serious inabilities, etc.

Reality suggests that most of your hands for forest management are tied:

(a) you don't have control over the funds;

(b) you have barrels and chains but no aerial herbicides;

(c) your forest inventory may be grossly inadequate;

(d) you're scared to death of the outcome of the Class Environmental Assessment for Timber Management; and

(e) you can't get out of TMP hassles, administration, etc.

We all know that; but you've got to bear up, find the time somewhere (perhaps even in the pickup on the way to the woods, or in the plane on the way to TDU workshops), and increase the attention you give to real planning, and increase your competence at it.

7. Forest managers have two main tool bags - a physical one (silviculture), and a planning one.

The planning tool bag is rich. There are good tools and bad tools, new tools and old tools, easy-to-use and not-so-easy-to-use tools, and developing and improving tools. The planning tool bag is expanding, and has tools for all combinations of time and space.

This volume contains descriptions on many stand tools for stand performance, e.g., site class indexes; yield tables and curves; Forest Ecosystem Classification (FEC, although this one spans boundaries); and pre-cut surveys. But there are also many very good treatment unit and forest-level planning tools, e.g., FEC (see special FEC section in this volume); forest simulators such as FORMAN (see Williams, this volume); treatment unit economic models (such as the one currently under development at the Northwestern Ontario Forest Technology Development Unit - TDU); and geographic information systems.

The point is that, as foresters, you must know and use your technical tools (e.g., site preparation, planting, tending, protection), but also your planning tools, especially the forest-level planning tools. These tools are not for the exclusive use of office foresters, planners and academics. They are being designed as aids for the field forester. Just as your tattered old copy of Smith(1986) and a bunch of OMNR silviculture guides might be in the pick-up glove box, a personal computer (PC) loaded with your favourite sets of equations (some of us call these models) for forest planning should be on your desk (or even with you in the woods, given the powerful portable PCs these days!). The PC is no more than a very fast calculator and data storer. The models are usually no more than linked sets of rudimentary equations. Together, they help you make calculations about the costs and benefits of your silvicultural prescriptions and actions.

Setting appropriate time and space contexts to guide local decisions is difficult work, but in the planning tool bag we have powerful, new analytical tools (mainly simulation models and GIS

facilitated by ever more capacious micro- and mini-computers) that can really help. The catch is, we have to understand them and use them.

8. Site-specific silviculture - what's the appropriate context?

Let's look at a typical stand-level decision. Why spend money on a specific treatment in a specific stand? There could be many reasons; here are some candidates that you may have heard (or even used):

(a) It's a good site! Look at those internodes!

(b) The stand needs improvement! It's a silvicultural slum!

(c) The stand will respond!

(d) The nursery sent us five truckloads of these damn seedlings!

(e) The equipment was handy in the area!

(f) The TDU said it was the right thing to do!

(g) KBM (Thunder Bay forestry contractor and consultant) offered us a great deal on the contract!

(h) It's the best habitat for wildlife!

(i) It ties up carbon in the stand, so it won't contribute to global warming!

(j) I learned it in silviculture class at the LU School of Forestry!

These are all essentially bad reasons. We should spend money on a specific stand with a specific treatment because it makes the greatest contribution to forest or treatment unit objectives of all the things we could do with the money!

9. Forest managers - be planners and be competent!

(a) Put silviculture in its proper context. Silviculture resides in the tool bags (physical and stand-level planning) that you need to fix forest problems. We should get the motherhood out of silviculture; challenge the rules and principles, experiment, calculate costs and consequences.

(b) Show the world, with your own credible analysis, what might be done and what can be done in your forest.

(c) Grab the good planning tools and use them in your personal, field-planning process. The important point is not which process a forester uses in setting field targets for silviculture and forest performance, but rather, it is to at least have a process. And we all know that these days, the process must include more than gut-feelings and back-of-the-envelope calculations.

(d) Challenge the planning tools; try them out, have a healthy skepticism, change them to suit yourself (in defensible ways of course, if you tamper with the basic biological relationships).

(e) Practise adaptive management, actively learning as forests get managed. There is so much uncertainty in long-term forest planning that investments in management-scale experiments (not lab experiments) are required to guide us through the evolving future.

(f) Despite your difficult real context, do your own rigorous planning; it may be the key to your retaining professional credibility as a forest manager.

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A NEW INTEGRATED FOREST RESOURCE PLAN FOR PONDEROSA PINE ON THE DESCHUTES NATIONAL FOREST

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ABSTRACT

The Deschutes National Forest has experienced a dramatic transition in timber management philosophies since the first commercial timber sales in the early 1920s. Strategies initially focused on development of access, fire suppression and risk-cutting the old growth ponderosa pine (Pinus ponderosa Laws.). This philosophy was replaced by a strong emphasis on even-aged management and an agricultural approach to forestry. The Deschutes published its Draft Forest Plan early in 1986. The Forest's many vocal publics opposed the plan's emphasis on even-aged management and suggested alternative practices. Based on these comments, managers looked for different silvicultural systems to manage ponderosa pine. Uneven-aged management is now the preferred silvicultural system in irregular, multi-aged ponderosa pine stands. This new strategy has the potential to better integrate the often conflicting needs of the Forest's many users into a viable forest resource plan.

EARLY MANAGEMENT IN PONDEROSA PINE

The first commercial timber sale on the Deschutes National Forest occurred in the early 1920s. Management strategies focused on development of access to the vast stands of yellow-barked overmature and mixed-age ponderosa pine (Pinus ponderosa Laws.). Timber sales provided access, as well as an opportunity for foresters to suppress periodic wild fires. Fire had played an important part in the development of these majestic stands on the

Deschutes. This influence would be largely eliminated in the future.

Timber harvested from the National Forest supplemented the growing demands for high value ponderosa pine made by local mills. Early timber management plans emphasized the removal of overmature, large diameter pine, which were at high risk of attack by western pine beetle (Dendroctonus brevicomis). Trees killed by pine beetle rapidly degraded in value. Risk rating schemes were developed which predicted trees in imminent danger of attack (Keen 1943). In theory, stands were to be entered on a 10-year cycle. Trees of value that were predicted to die within the next 10 years would be harvested at each entry.

In practice, stands with easy access were entered more frequently; those with difficult access, not at all. Because of the subjective nature of these systems, trees of greater or lesser risk were harvested to meet the prerogatives of forest managers. Other management systems, which evolved later, focused on the removal of groups of overmature trees that produced small openings in the high forest canopy (Hallin 1951). The removal of scattered, overmature trees, or groups of trees, provided additional growing space for regenerating thickets of ponderosa pine seedlings and saplings. Little attention was given to achieving stocking level control within thickets, or to establishing regeneration in created openings. The elimination of fire allowed the eventual development of a new mosaic of forest canopy layers.

Risk-cutting later moved up the slopes of the Cascades into the mixed conifer stands where ponderosa pine remained an overstory dominant. Here the results were different. Decadent white fir (Abies grandis (Dougl.) Lindl.) were rarely harvested. Residual white fir were commonly damaged by logging and problems caused by dwarf mistletoe (Arceuthobium campylopodum Engelm.), as well as stem and root rots, were aggravated. Newly established understories were white fir rather than ponderosa pine. Opportunities for the future management of mixed conifer would be limited by risk-cutting in these stands.

Management practices in ponderosa pine met objectives important at the time. Vast acres of unmanaged timber and small annual harvests relaxed concerns about forest regulation and the notion of a sustained yield. The influence of early forest management was subtle but important within these virgin ponderosa pine stands. Where foresters focused on the management of individual trees or groups of trees at risk, the high forest character of these stands was maintained. Harvesting practices and the elimination of fire created irregular, multi-storied stands of yellow-barked old growth, young growth poles and small sawtimber thickets of regeneration. Future generations would come to view these extensively managed pine forests as "natural" stands and, ultimately, these stands would become a model of the desired vegetative character for the ponderosa pine forests of the 1980s.

CHANGING MANAGEMENT STRATEGIES

In the years following World War II, a major transition in the philosophy of forest management occurred. Wood products from the northwest were essential, in order to fuel a growing, post-war economy. Increased demands in turn accelerated the harvest of National Forest timber. On the western slopes of Oregon and Washington, stands of overmature Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) and western hemlock (Tsuga heterophylla (Raf.) Sarg.) timber were harvested by clearcutting. State-of-the-art forestry on the western slope emphasized the management of stands of timber rather than individual trees. Foresters, supported by local forestry schools, expounded the virtues of even-aged management and a heavy handed agricultural approach to forestry.

Aggressive staff at Regional headquarters in Portland, sensitive to the growing reliance on National Forest timber and concerned about the production of a sustainable yield, strongly endorsed even-aged management. These tools were borrowed from the west slope and were eventually advocated for all National Forest lands in Oregon and Washington. Deschutes forest managers had seen limited use of clearcutting during the 1950s and 1960s, when it was

mostly applied to control dwarf mistletoe in heavily infested stands. In response to this new Regional initiative, foresters on the Deschutes looked at clearcutting as the preferred silvicultural tool. The conversion of slow-growing, diseased and overmature stands to fast-growing, disease-free and genetically superior young stands would satisfy the demand for wood products into the 21st century. By the late 1970s, the Forest was harvesting roughly 8,000 acres annually, using even-aged systems.

Along with this initiative came an increased commitment towards quality reforestation. Foresters concentrated on effective site preparation, quality planting stock, careful planting techniques and aggressive animal damage control. Large, district organizations evolved to meet the needs of this growing workload. Investment costs seemed of little concern to Forest managers. Emphasis was placed on quality work and achieving the highest possible degree of success. Plantations were commonly established at a cost of $500 to $800 per acre, and achieved 85-90 percent survival at the end of the third growing season.

New visions of intensively managed forests of the future were far different than those of pioneer forest managers. Contemporary foresters, committed to this heavy-handed agricultural approach, saw the National forest as a tree farm. Forests of the future would be dominated by a mosaic of 25-40 acre even-aged stands of healthy and intensively managed young-growth. New plans for clearcutting seemed particularly appropriate in mixed conifer stands on the slopes of the Cascades. Stands that had been repeatedly risk-cut had few redeeming features, which encouraged future management. This was not the case in irregular, multi-aged pine stands. Despite this new emphasis on clearcutting, foresters were hesitant to eliminate existing thickets of good quality saplings and poles. In most cases, these thickets were retained and managed.

By 1984, the forest had also adopted new standards for the management of cavity dependent wildlife. In all forest types, scattered, living, sawtimber-sized trees were retained to meet

these objectives for future cavity-dependent species habitat. As a result, irregular, multi-aged pine stands retained a suggestion of their original character. Despite wildlife trees, clearcuts in mixed conifer bore little resemblance to their earlier character.

On lands where scenic views were emphasized, 8-12 shelterwood trees per acre were retained to soften the visual change of the regeneration harvest. These stands were also planted to ensure prompt establishment of a new understory. Although shelterwood trees in scenic views were planned for removal, few foresters visualized this actually occurring. Even on lands where intensive timber management was emphasized, shelterwoods were commonly prescribed along with planting. Although "insurance" was the usual justification for the shelterwood, it also reflected many foresters' gut-felt reluctance to eliminate the "natural" character of these multi-age stands.

Although forest managers understood the incredible changes taking place in the "natural" landscapes that they had inherited, these changes were mostly interpreted as being positive. Foresters had little understanding of the far reaching effects that these landscape changes would have, as they were to be interpreted by a new, and perhaps enlightened public with conflicting values and different needs.

THE PUBLIC ISSUE

In compliance with the National Forest Management Act (NFMA) and other environmental laws, the Deschutes issued a Draft Forest Plan early in 1986. Planned timber management activities on the forest focused on even-aged management. More than 1,640 letters were received in reaction to the proposed plan, and at least 60 percent of those responding expressed strong opposition to clearcutting. Shelterwood cutting was viewed simply as a two-step clearcut. Few comments were received in support of either the current timber harvest activities or those proposed in the Draft Plan.

Comments in opposition to clearcutting came from both the timber industry and the environmental community. Most industry representatives advocated a return to selective cutting in ponderosa pine. They suggested management of individual trees for optimum growth rather than the broad brush stand management approach. Environmentalists countered that the timber industry was only interested in harvesting high value, large diameter trees.

Many people within the environmental community recommended the selection system or uneven-aged management as the preferred silvicultural strategy. Maintaining biological diversity was the overwhelming justification. Environmentalists were also concerned about the destruction of wildlife habitat and the conversion of our national heritage to a tree farm. Some claimed that our clearcutting practices were a violation of NFMA. Many environmentally-oriented respondents also felt that clearcutting was wasteful and uneconomical. Industry representatives contended that the environmentalists' real agenda was a prohibition on the harvesting of additional old growth ponderosa pine.

Deschutes forest managers were shocked at these responses to the Draft Plan. They were shocked by the far more vocal publics who likened the Deschutes' timber harvest areas to "festering sores on the back of a mangy old dog," and which were literally, "visible from outer space." Forest managers were frustrated because planned forest management objectives could only be achieved after decades or centuries, while the public's objectives for National Forest management seemed to change by the day. Behind these issues identified during the Forest planning process lay a common concern for the maintenance of the existing characteristic landscape.

During the late 1970s and early 1980s, Central Oregon experienced a serious economic recession and decrease in demand for National Forest timber. At the same time, Central Oregon's economy experienced increased growth in recreation and tourism. Critical local publics claimed that Central Oregon's future lay in these expanding industries, rather than the destructive and short sighted timber industry. Deschutes' managers struggled with the Forest's

many publics to strike a new balance between the consumptive needs of timber industry and the non-consumptive needs of new and growing industries, which apparently required some semblance of the "natural" landscape for their existence.

Indeed, the focus had shifted from the management of individual trees to timber stands. While early management practices maintained structural diversity and the "natural" landscape, contemporary practices seemed to simplify structural diversity. Early practices couldn't keep pace with the growing demand for wood products and changing philosophies on forest management, and current practices left heavy footprints on the landscape in order to meet new demands for forest products. Responses to the Draft Plan signalled that the time had come for a new look at forest management. Silvicultural systems were needed to ensure that this characteristic landscape focused on resource harmony and reduced conflicts between forest users, rather than intensifying them.

NEW STRATEGIES DEFINED

A commitment was made, by the Forest Management Team, to analyze the feasibility of adopting new silvicultural strategies which would address these concerns. Experienced forest managers understood that our publics were viewing but a "snapshot" in the inevitable evolution of these magnificent stands. Benign neglect could not ensure the maintenance of this desired landscape in the long run. While forest managers were concerned about long term landscape sustainability, some vocal publics seemed concerned only about the preservation of existing stands today. This conflict regarding perspective challenged the National Forest's responsibility to sustain both tangible and intangible outputs, including a desired landscape over time. The Forest needed different silvicultural systems that would make sense ecologically, that would be implementable, and that could sustain these diverse sets of outputs in the long run.

Before silvicultural strategies could be developed, the Forest's management team needed to gain consensus on the elements describing this characteristic landscape as it evolves in a managed condition. Such a description can be thought of as the "desired future condition" for these irregular, multi-aged stands. These elements shape the silvicultural systems, which in turn transform these "natural" landscapes into managed stands.

Management experience, particularly in the Forest's scenic views management areas, helped foresters identify these elements. Unlike lands with a timber emphasis, scenic views were managed with a strong commitment to maintenance of the characteristic landscape. Along the Forest's highway corridors, recreational areas and vistas, foresters looked to other cutting practices to maintain visual quality objectives using timber management as a tool. Here the stands were managed to maintain a high forest character and multiple canopy layers; or else they were opened up to highlight views and develop structural diversity. From these experiences, foresters and landscape architects gained a collective understanding of the elements important to this characteristic landscape.

Timber harvest activities which met visual quality objectives in scenic views and found widespread public acceptance typically had three elements in common. Small scale diversity was maintained using a mosaic of tree sizes and aggregations across the landscape. A few yellow-barked, larger diameter old growth were retained on most acres, either as aggregations or scattered individual trees. Harvested sites maintained a relatively undisturbed appearance by retaining portions of the existing understory of trees, shrubs and grasses, as well as duff and "natural" accumulations of woody debris.

Additionally, these managed stands, which represent the "desired future condition," would need to achieve growth and yield objectives that would assure a sustained harvest at appropriate levels.

Based on the identification of these relatively simple but essential elements, silvicultural strategies were developed. Over the years, foresters had attempted an incredible variety of silvicultural practices in the ponderosa pine forests. These results provided a clue to the array of practices which made sense ecologically and produced the "desired future condition." Silvicultural systems developed for the Deschutes were not new, but simply a reflection of the collective wisdom gained from observation of this vast management experience, including work done most recently for scenic views. From this experience, the essential components of a silvicultural strategy took form.

This new strategy, which seemed to maintain the characteristic landscape and achieve the "desired future condition" relies on several fundamental principles:

1. Maintain or develop at least three distinct canopy layers, which include yellow-barked old growth;

2. At each entry, harvest, as a priority, the highest risk, poorest quality trees, leaving behind a better quality, lower risk stand;

3. Achieve overall stocking level control in all tree sizes at each harvest entry;

4. Open ground for the establishment of new seedlings after each harvest entry, favouring natural regeneration where possible; and

5. Work with the existing stand structure to maintain occupancy by trees at stocking levels appropriate to the site and harvest interval.

These principles, first described as "multi-aged management" in an awkward attempt to avoid the controversy centring around "uneven-aged management" in the region, nevertheless fit neatly within the context of uneven-aged management. The notion of even-aged management had been firmly ingrained in the hearts and minds of many foresters. They were witness to the continued demand for ponderosa pine sawtimber, and understood the need to maintain healthy forests. Even-aged management was well known and its results were generally predictable; however, uneven-aged

management was another story. Some foresters suggested that the problem could be simply solved by educating the public about the correctness of our even-aged practices. In reality, our publics could be educated only when they wished to be educated.

The issue soon grew beyond the Deschutes, and standardized, correct terminology became essential. Uneven-aged management would indeed be seriously considered. This notion met with varied responses from forest managers. Many suggested timber yields would drop significantly. Management costs and complexities would dramatically increase, as would the potential for high-grading and the proliferation of insect and disease problems. Veteran managers on the Forest, whose careers had spanned the evolution of ponderosa pine management, saw this change in a more positive light. Local timber industry supported the change in strategy. They agreed that poor quality trees of low vigour should be harvested first, leaving behind stands of better quality and lower risk. Environmentalists saw this change as a step in the right direction. Few publics really understood the technical aspects of uneven-aged management. The notion was likely interpreted as a very different beast by the Forest's differing publics, as well as its own staff.

Before a transition could be made to uneven-aged management, the effect was tested within the context of the Draft Plan's preferred alternative, using the FORPLAN model (Johnson et al. 1980). The effect of this new strategy on the Forest's present net value (PNV), allowable sale quantity (ASQ) and long term sustained yield capacity (LTSYC) was evaluated. The analysis of uneven-aged management became a formidable task, which required the development of potential silvicultural prescriptions, identification of suitable stand and site conditions, development of new managed yield tables based on growth and yield modelling, new cost and value data, and the identification of applicable stand acres. This process was reported in detail at the National Silvicultural Workshop (Znerold 1987b) and IUFRO Forest Growth Modelling and Prediction Conference (Znerold 1987a).

In the context of FORPLAN, uneven-aged prescriptions seemed appropriate and were tested on 67 percent of the remaining inventory of mature and overmature pine and 20 percent of the mixed conifer. Results revealed that when the total of harvested and residual volumes were compared during a 150 year management cycle, there were no significant differences in yield between clearcutting and uneven-aged management in ponderosa pine. In mixed conifer, yields fell slightly. Because of this drop, as well as the timing of yields and increased costs applied to uneven-aged management, the Forest's PNV fell by four percent, a drop of $33 million over the 150 year planning period. The ASQ also fell by four percent, a drop of five million board feet annually, during the first decade. These impacts seemed reasonable enough to satisfy public concerns.

This early analysis is being refined as new analytical tools and growth simulation models become available. Today these predictions are based on an interpretation of stand relationships that we have yet to experience, and stand management practices we have yet to perfect. These predictions in no way detract from the silvicultural skills which can be applied today to maintain this "desired future condition." Many of the effects caused by this shift to uneven-aged management on the Deschutes will not be totally understood for decades, as was the case when the Forest shifted to risk-cutting and then to even-aged management.

Already advanced efforts at growth and yield modelling are providing new clues to the optimal application of these practices. Based on the performance of individual stand data from Forest inventory, volume growth seems strongly dependent on the configuration of the existing growing stock. Yields from irregular, multi-aged stands respond favourably to uneven-aged management. Yields from even-aged stands are reduced when subjected to uneven-aged strategies in the short run. These new efforts confirm the intuitive need to work with existing stand structures rather than employ heavy handed corrective cutting to

bring stands into an ideal diameter distribution too quickly. Over a period of many decades, stands can be brought into regulation.

IMPLEMENTATION BEGINS

The Forest cautiously began testing uneven-aged prescriptions in timber sales planned in 1987. Management direction was written which gave emphasis to uneven-aged management in irregular, multi-aged ponderosa pine stands and the preservation of options for the future. Silviculturists developed prescriptions which were guided by the standards and guidelines developed to ensure consistent implementation of these new practices. During 1988, timber sales using uneven-aged management were planned on all districts. Several sales were sold and harvested. Timber planning teams wrestled with the application of a silvicultural system they had no practical experience using. These harvested, uneven-aged stands certainly bear resemblance to irregular, multi-aged stands managed with even-aged strategies. Where thickets of advanced regeneration, wildlife trees and shelterwood trees were retained before, few publics will notice much difference in the short run using uneven-aged management. In the long run, strong emphasis will be placed on the management of a more ideal distribution of tree sizes, including additional immature, but merchantable, trees along with regeneration and scattered yellow-barked veterans. Future sales will no doubt be planned with more confidence, having gained a little better understanding of the shape of this beast called uneven-aged management.

Foresters still have reservations about the misapplication of these new strategies, particularly in mixed conifer stands. There is concern that the pendulum of management philosophy will swing too far again, encompassing stands where it just doesn't make sense to use uneven-aged management. It is certainly no panacea. There are important considerations relative to stand structure, species composition and long term forest health. Managers worry about the applicability of uneven-aged management on steep slopes and on soils which are easily compacted or displaced. Concerns about

growth and yield and the economics of uneven-aged management will only be adequately addressed after decades of experience. It is important that these new practices be carefully managed and closely monitored if questions are to be answered for future foresters. Already, the Deschutes has initiated long-term plans for monitoring these important aspects of uneven-aged management.

It has become apparent that these new strategies have the potential of meeting a surprising multitude of management objectives for wildlife habitat, scenic views, recreation, and the production of sustained yields of sawtimber over time. Uneven-aged prescriptions easily meet visual quality objectives associated with scenic views. Concerns about future habitat for cavity dependent wildlife are minimized when trees of all sizes are retained. Small scale structural diversity is easily maintained. Constraints associated with maximum harvest unit sizes and the adjacency of treatment areas are eliminated. Uneven-aged management seems to satisfactorily integrate many of these potentially competing demands on the Forest.

It has also become apparent that uneven-aged management has its limitations. Stands which are managed tend to look managed. Uneven-aged management is no exception. To maintain growth and yield objectives, careful stocking level control is needed. These managed stands are far less dense, and far more vigorous than their "natural" counterparts. Those publics who advocate preservation of existing stands will not be satisfied by uneven-aged management. Because of the reduced densities, wildlife biologists are doubtful that these managed uneven-aged stands will provide good habitat for deer and elk. As more experience is gained, these relationships will be better understood.

The Forest has made an incredible transition in timber management philosophy in the past several years. This is certainly to the credit of responsive forest managers, who have learned many hard lessons in the process. The Draft Forest Plan gave the public a new and more effective forum to express their viewpoints. Forest

managers learned that these really are the public's national forests, and they really would like a say in how they are managed.

Managers struggled to strike a balance between these vocal publics' competing needs. Uneven-aged management blends some attributes of earlier systems, including retention of a high forest character, with attributes of even-aged systems, including consideration for regeneration, density management and a sustained yield over time. These shared attributes should reduce conflicts, foster new harmony and lead to more viable resource management plans. Uneven-aged management in ponderosa pine makes the vision of multiple-use management a little clearer.

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DEVELOPMENT OF A PRIME SITE STRATEGY: CASE STUDY ON THE RED LAKE CROWN MANAGEMENT UNIT IN NORTHWESTERN ONTARIO

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INTRODUCTION

The objective of this case study is to outline a Prime Site Model and indicate how it incorporates factors of biology, economics and spacial geography into timber management planning. This model will be used to strategically develop silviculture systems and to priorize the implementation of an annual regeneration program.

The Red Lake Crown Management Unit (RLCMU) can be found at the northwest corner of the Province of Ontario. It is one of the most northern management units that the province of Ontario manages for fibre production.

The Unit was one of the first Management Units that followed the new Province of Ontario Timber Management Planning (TMP) system. During the fall of 1989 a new plan will be prepared for implementation April 1, 1991.

After the district identified the objectives of the study, a review of existing tools and information was carried out.

Two basic silviculture analysis models have been reviewed, U.S. Forest Service Quick Silver Model and a Net Present Value Model that Roy Sidders developed while at the Thunder Bay District.

The information put together for a data bank was:

1. Soils Information - NOGETS;
2. FEC Classification for Northwestern Ontario
   - field data and the system itself;
3. Silvicultural Records
   - historic unit costs;
4. Operational Cruise Data; and

5. Yield Tables - Plonski
   - Variable Density Yield Tables.

MODEL FRAMEWORK

The economic framework for this model simply stated is:

$$\text{Net Present Value} = \frac{\text{Timber Revenues} \times \text{Yield} \times 1.005^{\text{Rotation}} - \text{Silvicultural Expenditures} \times 1.0495^{\text{Rotation}}}{1.0495^{\text{Rotation}} - 1}$$

An effort was made to make the model as practical and understandable to facilitate actual use by resource managers.

MODEL COMPONENTS

The following list indicates the various inter-related components of the model.

1. Economic Factors of Timber Production
   i) Average Annual Increase in the Value of Timber Products
   ii) Product Rotation - Compounding Period
   iii) Economic Spatial Comparison of Site - Haul Cost Zones

2. Silvicultural Treatment Intensity
   i) Treatment Costs - Time Frame Incurred
   ii) Real Interest Rate
   iii) Rotation - Initial Spacing or Degree of Spacing Control
   iv) Probability of Treatment Success

3. Site Productivity
   i) FEC Correlated to Yield Classes
   ii) Plonski Site Classes

Two key factors of the components included in the model are:

i) Spacial geography based on economics; a haul cost estimation formula is used; and

ii) Two 20-year interest rates are used, silvicultural expenditures are compounded by the 20-year historic difference between the prime lending rate and the inflation rate (<u>real</u> interest rate), and future timber revenues are compounded by the 20-year difference between the increase in the pulp and paper/sawmill price index and the inflation rate (<u>real</u> increase in the value of timber products).

DISCUSSION

The case study is anticipated to be completed by June of 1990.

Preliminary indications are that site productivity is the most significant factor in the economic analysis with distance to mill facilities (haul cost) of lesser influence.

The final outputs will be:

i) Development of a "Prime Site" strategy on the 1991-2011 RLCMU TMP;

ii) A method of annually evaluating the silvicultural expenditure priorities; and

iii) A relative indication of the importance of site productivity and the distance to mill complexes and the inter-relation of these two key factors.

SITE-SPECIFIC DECISION MAKING ON INDUSTRIAL FORESTS

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ABSTRACT

Although timberland owners may have different goals and objectives, the thought process to intensively manage a forest is essentially the same. The "context" of silviculture is set by forestwide planning activities, but site-specific silvicultural prescriptions rather than blanket prescriptions are required to maximize returns from the forest.

Site-specific decisions should be made for all silvicultural activities including: site preparation, planting, tending, spacing, and fertilization. Each of these topics is briefly discussed in the following pages and simple techniques for evaluating the returns from each are developed.

INTRODUCTION

The methods of timberland management are dependent upon the goals and objectives of the owner. Industrial timberland owners in the United States generally have a very simple objective, which is to produce the greatest return possible for the corporate shareholders. Given that goal, it may seem that forestry methods for the United States industry and the Canadian government would be very different. While methods may differ, the thought process for intensive forest management, whatever the goal, is very similar. The purpose of this paper is to examine the rationale behind site-specific silvicultural prescriptions, as applied to industrial forests in the United States, with implications for land managed by the provincial government of Ontario.

The Context of Site-specific Silviculture

Silvicultural prescriptions cannot be made in a vacuum. They must be made with regard to the overall goals and objectives of the owner. The goal of a business is usually to maximize the long-term return on the investment. The long-term nature of a forest enterprise cannot be over-emphasized. Since the returns from current investments are usually decades away, a short-sighted view will miss many opportunities. Any ongoing operations will also require a fairly consistent cash flow, wood supply, etc., which may constrain specific activities in the woods.

To determine the best method of attaining the long-term goal, we can ask two basic questions: 1) "What can I grow?" This is the biology of site-specific silviculture which is the subject of the bulk of this paper; and 2) "What do I want to grow?" These are the products that the forest is being asked to produce or the "context" of silviculture.

Generally, the production requirements have very little to do with the forest itself. They come from what might collectively be termed "bureaucrats." These are the folks who all have their needs from the forest, but little perspective on the overall picture. Examples might be accountants, mill managers, politicians, logging engineers, or environmentalists. Meeting their individual goals puts constraints on the management of the forest, but must be satisfied to meet the overall objective of maximizing returns.

Unfortunately, the forest itself also imposes some constraints on management. The truly regulated forest is most likely a myth. There are always some problems such as: age gaps, bugs, fire, or wrong species that confound the management alternatives.

So, with all of these constraints and alternatives, how do you pick the best option to achieve your long-term goals and objectives? The traditional approach has been to optimize what you have through the use of linear programming. This technique examines all the potential scenarios, in light of the present conditions and constraints, to maximize an objective function, which is usually net present value of the timberland asset. There

are a number of published and commercially available programs along with many custom versions tailored to specific companies and operations. These models, with all of the timber types, yields, silviculture, and constraints built in, give the general context of site-specific silviculture in terms of harvest levels and silvicultural activities that maximize returns. It is up to the field forester to apply these guidelines in specific situations. For example, if the model says an operating area (management unit, tree farm, timber shed, forest) should produce aspen (Populus spp.) to supply a mill, and a silviculturist decides it is better to spray glyphosate and plant black spruce (Picea mariana (Mill.) B.S.P.), then there is a conflict between the general and the specific. While the spraying and planting may be sound silviculture, they do not, in this example, generate the maximum return for the enterprise, i.e., they are taken out of "context."

Site-specific Decision Making

With the overall context of forest management in mind, it is the site-specific prescription we want to concentrate on. How do you optimize what is going to be done on an individual stand basis? The individual stand should really be emphasized. No two stands are exactly alike so it makes sense that each area should be evaluated individually. We have a tendency to make blanket prescriptions for the forest. While the forest is very forgiving and will probably survive our imprecisions, the waste of money or opportunities lost can be tremendous.

Imagine, if you will, a new clearcut; we are going to go through the thought process of intensive, site-specific silviculture on that unit. If in fact, we begin the process with a clearcut, we have already missed two opportunities for intensive management. We should have planned ahead for the type of seedlings to be planted. For example, suppose a site was best suited to loblolly pine (Pinus taeda L.) but the only seedlings we had were slash pine (Pinus elliottii Engelm.). If the slash is planted, we lose harvest volume at the end of the rotation. If we wait a year

to get some loblolly seedlings, it costs time, and time is money. This is a "no win" situation that planning would have solved. The second opportunity lost might be site preparation help from the logging. By selecting the logging method and how the activities are carried out, benefits can be derived in slash reduction, brush removal, and seed bed preparation.

Site preparation

If given the choice, foresters would probable prefer to plant flat rototilled fields. That way you can plant as many trees as you want on exact spacings. But is that necessary? To get a ballpark estimate of whether a proposed silvicultural activity is economically viable, there is a technique called "envelope economics." The necessary tools are: a pencil, a calculator that does discounting, and the back of an envelope (although any scrap of paper will do). Let's go through an example of this technique using site preparation. Assume it has been previously determined (how to do this will be discussed later) that planting 400 Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) trees per acre is the ideal economic spacing. Based on growth model data, such a plantation will produce 40 MBF (thousand board feet) per acre at age 50. Stumpage value is $100/MBF, so the future timber value is $4,000. Discounted at 6% for 50 years, the present value is $217/acre. Now suppose we have a clearcut in which it is obvious we cannot plant the ideal spacing, the immediate reaction is to site prepare it. But is that the wisest choice? Through use of a preplanting survey, it is determined we could plant 200 trees/acre. Again, using a growth model, such a plantation would produce 30 MBF per acre at age 50. Using the same values as above, the future value of this less-than-ideal plantation is $3,000 and the present value is $163/acre. The question becomes: Can I site prepare this unit for $54/acre ($217-$163)? If the answer is yes, the best choice is to do site preparation and plant 400 trees. If the answer is no, the best economic choice is to plant the unit as is, although we will suffer a volume reduction at rotation.

This example is extremely simplified, but portrays the basic thought processes in making a choice to site prepare or not. Other factors which may be considered include: seedling survival, real stumpage escalation, taxes, rotation length, and logging costs. However simple or complicated you make the analysis, the objective is still the same; i.e., to determine if the ideal spacing achieved through site preparation is financially attractive or not. Now, let's talk a little more about the ideal spacing that we are striving for.

Planting

There are two major considerations when determining the optimum planting density. The first is the productivity potential of the site and species you are dealing with. The second is the economics involved in the biological scenario.

Production Potential

There seems to be substantial evidence to support the ecological theorem that a given site will support a fixed maximum amount of biomass of a particular species. The size of the individual plants is dependent on the total number of plants present, i.e., if the biological maximum is reached with fewer individuals, they will be bigger.

This has a very important application for forestry. The fewer trees we plant, the bigger they will be. Assuming that the maximum volume we can produce is fixed over a wide range of densities, what we must concentrate on is producing the most valuable, merchantable volume.

This principle seems to apply to trees as shown in Figure 1. All of the planting densities for Douglas-fir above 400 stems per acre show essentially the same merchantable harvest volume as projected by a growth model. This principle is probably true for most species. It is a matter of finding out what the level is.

Economic Considerations

The economics of the Douglas-fir example above are quite simple. If I get no more merchantable volume by planting more than 400 trees/acre, there is absolutely no reason to plant more trees. It costs money for seedlings and planting labour. As density increases, the individual trees get smaller so the value of the wood goes down and the logging costs increase.

What is really necessary, rather than a set of volume curves as in Figure 1, is a set of economic curves with the biology (yields), costs (planting), and returns ($/MBF stumpage = wood value - logging costs). These would vary on a unit-by-unit basis, depending on what is there in terms of site, species, costs, and what you are trying to grow. Essentially, an economic rotation is being developed by balancing the present costs and future returns to obtain the maximum present value of the unit.

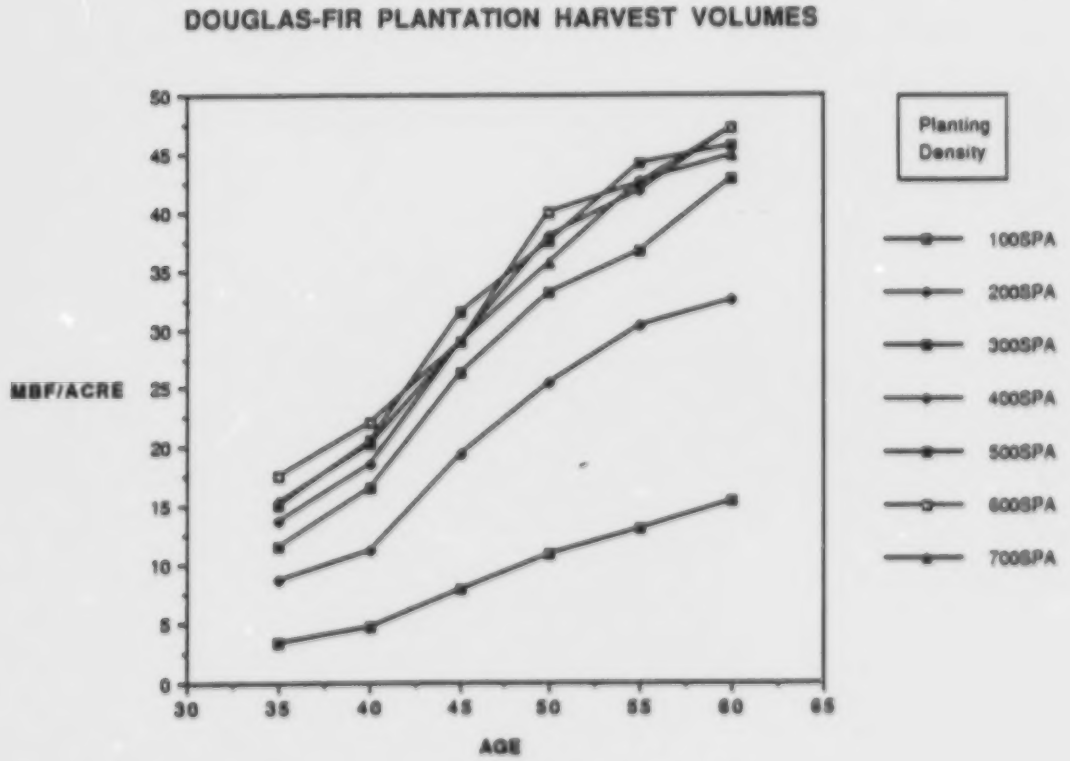

Figure 1. Example of a Fixed Maximum Yield.

Intermediate Operations

Unfortunately, the forest is not a static entity. Once you have the right number of the right species at the ideal spacing on the best site, it never stays that way.

Tending (Reproduction Release)

Unwanted vegetation, "brush," seems to be one of the universal truths of forestry. Whether it is hazel here in Ontario, raspberry in New England, hardwoods in the south, ninebark in the Intermountain west, or salmonberry on the West Coast, brush is a constant source of competition to young plantations. This competition can be expressed in two ways: 1) it reduces stand yields; and 2) it can change the timing of the revenues.

Evaluating the economic benefits of tending in the case of reduced stand yields is exactly the same as discussed under site preparation. You calculate the value of your ideal brushless stand, then you calculate the value of the stand with its yields reduced by brush. If you can spray for less than the difference, a herbicide treatment is warranted.

Often brush will not kill the trees, but will slow their growth for a number of years. The effect of this is to increase the rotation length which defers the revenue from the plantation. For example, if your ideal rotation is 50 years, brush competition may extend that to 55 years. For this type of situation, you use a slightly different analysis approach. We look at the cash flow stream to determine the rate of return on our investment. This is commonly called the IRR (internal rate of return). Figure 2 is an example of this approach from the southern United States. A plantation is established for $100, has annual management costs of $4.00, gets commercially thinned at ages 15, 20, 25, and is clearcut at age 30. The return for this scenario is 12%. With a herbicide application, there is an additional cost of $20 at age 3, but the harvests are now taken at 12, 17, 22 and 27. The IRR for this option is 14%. It is pretty simple to decide if you want 12% or 14% return on your money, so in this example you spray.

SOUTHERN HERBICIDE EVALUATION

CASHFLOW BY YEAR		Normal	Herbicide
YEAR	0	(100)	(100)
YEAR	1	(4)	(4)
YEAR	2	(4)	(4)
YEAR	3	(4)	(20)
YEAR	4	(4)	(4)
YEAR	5	(4)	(4)
YEAR	6	(4)	(4)
YEAR	7	(4)	(4)
YEAR	8	(4)	(4)
YEAR	9	(4)	(4)
YEAR	10	(4)	(4)
YEAR	11	(4)	(4)
YEAR	12	(4)	100
YEAR	13	(4)	(4)
YEAR	14	(4)	(4)
YEAR	15	100	(4)
YEAR	16	(4)	(4)
YEAR	17	(4)	200
YEAR	18	(4)	(4)
YEAR	19	(4)	(4)
YEAR	20	200	(4)
YEAR	21	(4)	(4)
YEAR	22	(4)	500
YEAR	23	(4)	(4)
YEAR	24	(4)	(4)
YEAR	25	500	(4)
YEAR	26	(4)	(4)
YEAR	27	(4)	2,000
YEAR	28	(4)	
YEAR	29	(4)	
YEAR	30	2,000	
	IRR =	12%	14%

Figure 2. Example of a Discounted Cashflow Analysis.

Spacing (Precommercial Thinning -- PCT)

Another situation that diverges from the ideal stand is when you have too many trees. It is immaterial how you get to the overstocked condition. There are examples of actually planting too many trees. In that case, you spent money planting extra trees and now you have to spend more money to cut them down. Seeding also tends to cause overstocking. It seems that seeding either fails completely or every seed sown germinates so you get thousands of trees per acre. Natural seeding from adjacent stands is also common.

It is possible to calculate the value of any stand depending on its current density. The computation is similar to the previous example of planting density. Figure 3 shows an example of present values of future harvests varied by current stand density. Assuming there are excess trees in a unit, you can create any spacing you want for the cost of cutting the extra trees. Again, an ideal PCT density can be calculated just like planting. This spacing and the associated value is fixed for a given age, site, and species. This value can then be compared to the value of the overstocked stand to determine if spacing is beneficial. Figure 4 is an example of this decision-making process.

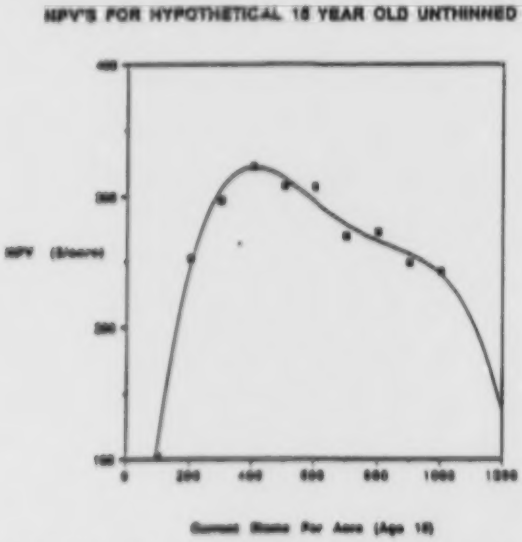

Figure 3. Example calculation of current stand values for varying densities.

JUVENILE SPACING IMPACT ON NET PRESENT VALUE

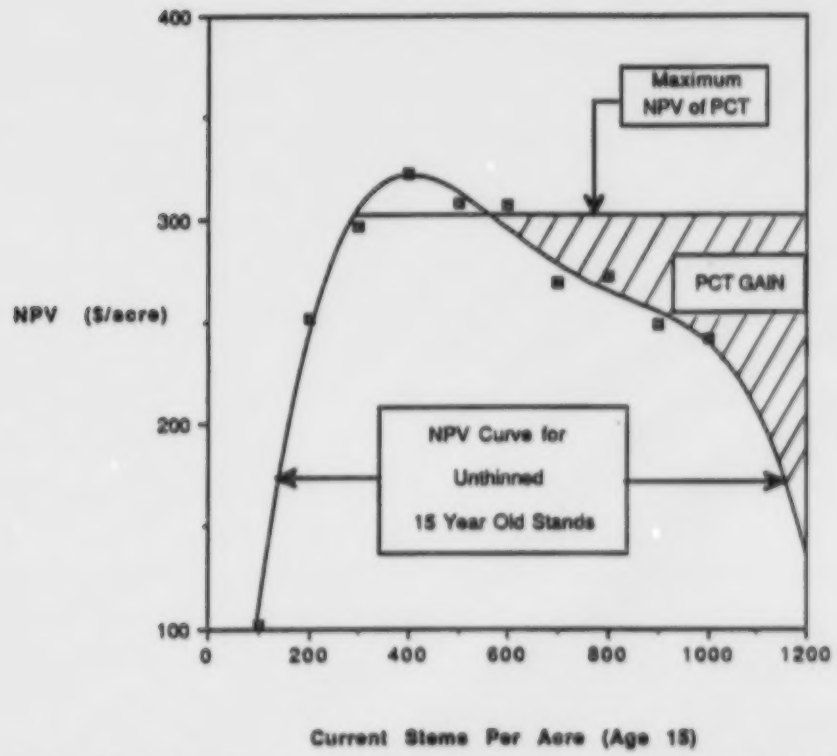

Figure 4. Comparison of the value of natural and spaced stands.

Fertilization

Fertilization is kind of the "icing on the cake" for intensive management. If everything else is right, you might want to consider a little extra boost of growth from fertilizer. To evaluate this option, we can use the back of the envelope again. Suppose you can get a growth response of 1/2 cord/acre/year for six years from fertilization; this is a total of three cords. If the stumpage value is $20/cord, the future value would be $60, discounted back at 6% for six years gives a present value of $42/acre. Therefore, if you can fertilize for less than $42/acre, it makes economic sense to do so. Notice the assumtion to harvest in six years. What if you cannot? By delaying the harvest, you must discount the returns longer, which decreases the present

value. Timing of the harvest is a critical factor in assessing the benefits of fertilization.

CONCLUSION

The intent of this paper was to briefly look at some of the more common silvicultural activities and present methods of determining if they make economic sense. The examples were purposefully very general and not applicable to the local area; the point being that each individual site needs to be evaluated on its own site-specific silviculture. In the context of the overall goals and objectives of the forest, site-specific silviculture is the only silviculture that we will be able to afford in the future.

SITE-SPECIFIC SILVICULTURE - APPLYING THE PRINCIPLES STRATEGY FOR LAKEHEAD WOODLANDS, ABITIBI-PRICE INC.

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ABSTRACT

The early entrance of Abitibi-Price Inc. (at its Lakehead Woodlands Division) into more intensive silviculture, including renewal and tending, is described in relation to the company's objective and strategy. The program is dependent on limited financing from both the company and the public.

Treatments are chosen for their potential to satisfy the company's mills' requirements around the year 2040 and later. Planting of black spruce (Picea mariana (Mill.) B.S.P.) is felt to be the best alternative. The best planting stock available is planted on the most productive sites closest to the mills. The largest and most vigorous stock is allocated to the sites with the most severe competition.

Seeding is done, when money is available and/or planting stock is scarce, where the sites are receptive.

A preference is expressed for lighter site preparation equipment; sturdy, well-balanced planting stock; and close supervision of seeding.

The author calls for improved forest management models that will be more sensitive to input variables including site.

BACKGROUND

The Spruce River Forest was, until April 1, 1981, a portion of timber licence number 328000 and was known as the Provincial Paper Limited. It was the prime timber supply area for the Provincial fine paper mill in Thunder Bay, which was acquired by the Abitibi Power and Paper Company, now Abitibi-Price Incorporated

(API). In 1981, it became the sixth forest management agreement (FMA) area in Ontario.

API realized in the early 1970s that the level of forest management being practised on its timber limits in Ontario was insufficient to sustain its mills. The company felt that the best opportunity to sustain its requirements for the Thunder Bay mills was on six blocks of its freehold land, totalling approximately 1,469 square kilometres, located along Highway 11/17, northwest of Thunder Bay. These lands were insufficient to satisfy all its needs, but they could certainly augment the supply from public lands and help to alleviate the consequences of shifts in public forest management policy and practice.

A recommended plan of development was drafted by then Professor Ken Armson of the University of Toronto, who was under contract with the company. The plan, given approval in principle by the company board of directors in April 1976, was based on maximizing the softwood fibre production by harvesting at an accelerated rate and planting jack pine (Pinus banksiana Lamb.). The majority of soils on the freehold are sandy loam over deep fine sands and are ideally suited to growing jack pine. The marketing rationale for this plan was:

1. At the time, API owned Northern Wood Preservers (NWP) in Thunder Bay, which it had recently purchased. This mill was producing poles, railway ties, and preservative treated lumber. Jack pine was the most demanded species for these products.

2. The company also owned the Hudson studmill near Sioux Lookout, which had a demand for white spruce (Picea glauca (Moench) Voss) black spruce (Picea mariana (Mill.) B.S.P.), and jack pine sawlogs. The company was investigating the potential for various options for expansion in the Lakehead. This was a routine analysis that the company goes through periodically.

The predominance of overmature stands was looked at as an opportunity to practise accelerated harvest to replace wood from more distant sources. This was practical, provided that higher-yielding new stands could be regenerated.

Work on the forest management program began on schedule in 1975. The initial trees were grown through a short term co-operative program by the federal forestry service at Sault Ste. Marie. These trees were planted in Block 2, near Rait., in 1976. Meanwhile, the company constructed two plastic greenhouses at its Camp 228 on the Spruce River Road. These houses were to be used to develop techniques to grow the trees for an expanding program. Development continued along plans until 1981. Stated goals of the program were:

1. to triple the growth per unit of area;
2. to reduce the rotation age by 50%; and
3. to double the annual area allocated for harvesting.

Professor Armson prescribed the following, to achieve these goals:

1. Plant jack pine, which would generally produce more growth over a wider range of soil conditions and was less sensitive to soils of lower fertility than were the spruces;

2. Control undesired vegetation by using herbicides and use appropriate site preparation;

3. Planting at optimum spacing of 1.8 x 1.8 m;

4. Priority for treatment should be given to those soils with the greatest capacity to grow jack pine, i.e., soils of intermediate texture with supplementary water supply; and

5. The efficient production of high quality planting stock with increasing attention paid to tree improvement.

Armson also speculated that the major benefit of beginning with a small operation would be the experience gained. That experience would give an insight into the possibilities for large-scale silviculture yielding high volumes on short rotations.

Armson was not necessarily being prophetic, because in 1976 he also wrote a report on forest management for the Ontario government (Armson 1976). In that report, he recommended FMAs as a mechanism whereby industry could take on the management of its timber licensed on a contractual basis for Ontario. This was

definitely a possibility for large scale silviculture, and API immediately saw the possibilities and signed the first FMA in the province covering part of its Iroquois Falls licence in 1980. In 1981 the company signed a second FMA, this one for part of its licences at Thunder Bay, called the Spruce River Forest FMA 500700.

The experience gained on the division's freehold was invaluable. Meanwhile, however, the markets that the company was engaged in were in a rapid change. The Hudson sawmill had been sold. The Thunder Bay 46 fire of 1980 had destroyed 10% of the division's mean annual depletion (MAD) and most of its prime pine sawlog supply. In 1982, the Northern Wood Preservers mill was also sold, but with commitments by API to continue to supply sawlogs from its own operations, and to guarantee a minimum MAD from its freehold. Other agreements with third parties allowed for exchanges of pine for spruce so that, in effect, a pine tree became somewhat like a spruce tree.

These rapid changes caused a realignment of company strategy to meet the new realities. As senior management changed its game plan for corporate strategy, Woodlands was required to change to meet the new supply requirements. The company thus entered the FMA with its future closely tied to the spruce and balsam fir (Abies balsamea (L.) Mill.) as a staple diet for its two newsprint and one fine paper mills in Thunder Bay.

Management made it clear that wood costs at the Lakehead were unacceptably high in light of other Canadian operations. Lakehead Woodlands was in direct competition with others within the company for scarce dollars, and not just competing with others' silviculture programs, but with all requirements. Pollution abatement was high on the company priority list, along with technology to increase yield from wood and ease the pressure on our wood supplies. Mill upgrading was essential if we were to remain competitive in a changing world.

Despite the sales of sawmills and related downsizing, forestry expenditures for API actually increased through the 1981-1983 period at the outset of the deep recession. These expenditures

were maintained even on the freehold where temporary curtailment would have been understandable.

This background then sets the tone for Abitibi-Price's approach to site-specific silviculture.

OBJECTIVES

API's objective is then intricately tied to the needs of its existing mills at Thunder Bay for a guaranteed availability of quality spruce and balsam fir fibre.

This objective is conditioned by the availability of scarce dollars. The company's foresters have a professional responsibility to get the most for money spent, no matter what the source.

The current objective of API's silviculture program at the Lakehead is to sustain 714,000 cubic metres of spruce and fir fibre supply for status quo mills from the FMA (i.e., the MAD at signing of the FMA).

That objective is to be met by:

1. Harvesting the Spruce River Forest under the rules of the FMA; i.e., (a) allocate the full MAD, (b) harvest the oldest first, and (c) regenerate to ensure the new forest and residual inventory can sustain current spruce/fir requirements when stands resulting from our efforts are available for harvesting;

2. Harvesting other licences to supply interim needs as the FMA MAD falls until plantations push MAD volume availability back up to the required level in approximately 2040; i.e., limit sustained yield; and

3. Continue the current management program on the freehold, but plant spruce and regenerate jack pine naturally or by seeding.

The latter is to sustain the company's outside commitments and retain the freehold in a viable condition.

CHOOSING THE APPROPRIATE METHODS

It is apparent that with scarce dollars, a definite preference for spruce (as in black), and only 47 years to fill a partial wood fibre gap, API's option is to get the most for its money with the most promising methods on the most suitable sites.

The division's strategy follows this trend:

1. Determine the number of trees available for planting (this is subject to the MNR's decree for the FMA);

2. Areas chosen for site preparation for planting are those sites closest to the mill and/or most likely to give the best yield; i.e., fine fresh to moist soils. This may imply conversion from mixedwood or hardwood to spruce. This is done knowing only a portion of the hardwood can be treated in this way, and that some of the softwoods on high competition sites will regenerate to hardwoods as they have in the past. Experience has shown the cost of conversion is no different from that of planting spruce after harvesting of spruce working groups on the same soils;

3. In planning site preparation it is assumed each year that the timber management plan (TMP) approved level of planting stock will be allocated. It is the only stable and predictable base available;

4. The available trees are allocated to the prepared sites most likely to give the best yield and/or showing low evidence of extreme plant competition;

5. Should the available seedlings not be sufficient to plant the inventory of site prepared area, those locations having severe grass, brush, or poplar are site prepared with the herbicide Vision. This has become the preferred treatment sequence for highly competitive sites as it appears to eliminate the need for tending or at worst delay a tending until a narrower spectrum herbicide would be sufficient. The use of Vision for site preparation reduces the degree of grass and raspberry competition during the critical first two years of the plantation's development. This appears to result in higher survival and more uniform growth. Future survival plot data is looked to for confirmation or rejection of this theory;

6. During each of the past four years, the company has had to deal with the fact that the MNR was not supplying the TMP approved number of trees. In addition to chemical site preparation of rich, fresh to moist soils, to hold them for later planting, some of the coarser, dryer, less fertile soils have been aerial or ground seeded;

7. Where a spruce seed source is available in standing trees, such as along wildlife corridors, stream and lakeside reserves, other reserves, and edges of uncut, non-allocated stands, site preparation has been done to the stand edge. An unplanted band, approximately two tree heights (30 m) wide, along the stand has usually been left to regenerate naturally from seed in the standing fringe;

8. In lowland areas where there is a fringe of uncut cone bearing trees and sufficient sphagnum moss seed bed, there is a tendency to forego site preparation as far as the sphagnum moss extends. Experience is showing that these areas are regenerating regardless of distance from seed source;

9. Since the first years of the FMA, the company has decided it will depend on natural regeneration or site preparation and seeding prescriptions for areas north of the Thunder Bay 46 burn of 1980. That is roughly equal to 10% of the land area of the FMA. That decision was based mainly on the area being more remote from our mills, but also somewhat on the relative predominance of coarser soils and jack pine predominance on the area. With tree shortages and increasing restrictions on financing of site preparation for natural regeneration or seeding, that strategy could become "leave for natural regeneration";

10. Where soils are on the margin between more and less productive they are not planted because of tree shortages; for such soils we have recently been trying Cerkon cone shelter seeding. This year, however, that option has been removed as it was not approved for funding in the annual work schedule by the Ministry;

11. All planting has continued at 1.8 x 1.8 m spacing to get the highest practical volume at age 50 years on the area planted; and

12. Tending has been an option for all sites until 1989. Each year those artificially and naturally regenerating areas that surveys have shown to be suppressed, have been proposed for tending and approved for funding. The 1989 AWS, however, has reduced the area that will be paid for. Our response has been to direct almost all of the approved money to plantations, leaving a small amount for naturally regenerated areas (less than 100 ha). During the past two years the MNR has required an untended strip along the edges of all reserves to leave browse species for wildlife utilizing the reserves for cover. This has been an additional factor in the decision to regenerate these areas naturally. There is no point in planting ground with scarce trees if you are not going to be able to protect the investment.

These then, are the silvicultural prescriptions we have been using with increasing frequency as the amount of money allocated by the MNR to silviculture has decreased. Meanwhile, there is probably an increasing area of not sufficiently regenerated (NSR) area developing on the better sites because there are not enough trees allocated to site prepare for seeding. Without planting, many former softwood stands tend toward hardwood brush or poplar, and without site preparation many jack pine stands regenerate inadequately. It is too early to be certain of this, but the former types are the areas that made up most of the NSR 3 and 4 treated in the early years of the FMA.

A possible impact of this is lack of ability to meet the objective of sustaining the cut on the FMA. Should that occur, it would affect the tree API paper mills, area sawmills and other pulp mills dependent on the contribution to the area wood pool. Company foresters are currently assembling data preparing to examine the potential impact of these strategies on the combined MAD of all lands for which the company is responsible at the Lakehead Division.

CHOOSING THE EQUIPMENT TO USE

Harvesting

There has been almost a complete move to full tree to roadside harvesting in recent years, both on the FMA and on our freehold.

Coupled with the move to full tree to roadside has been increased mechanization of all phases of the harvesting process. One of the big reasons for that move is the increased safety to manpower which has helped to make mechanization more acceptable and economical.

The result of this is cleaner harvesting, and accumulation of slash at roadside. Available methods to reduce this roadside accumulation and possible consequent loss of productive area to the next rotation, are currently being examined. Attempts to date have concentrated on burning the slash piles in the fall. However, this has been less than effective. On one freehold block, slash has been accumulated with a brush rake into circular piles rather than the larger rectangular piles as left by the de-limbers.

Site Preparation

The move to mechanization has also meant leaving some of the trees on steeper slopes and rocky knolls that may have been cut in the manual cut and skid operations. These trees are also being relied upon in some instances to provide seed on areas that can be site prepared close by. With the cleaner, more slash-free conditions, lighter site preparation machinery is now becoming practical. This enables holding the site preparation cost relatively steady. There is a trend toward Bracke and TTS Delta, away from heavy drags and other tractor hauled equipment. The lighter equipment has the extra advantage that it should cause less soil compaction. The Bracke is chosen for thinner, organic layered, steepest slope, and lightest slash areas. The TTS Delta is chosen for thicker organic layered, shallow sloped areas with heavier slash and/or brush.

Where required, aerial application is the preferred chemical site preparation method because treatments to date result in better coverage than has been achieved with ground application, and it is cheaper than ground application. The preferred herbicide has been Vision because it is the only herbicide effective against grass and raspberry, the main competing species on treated sites, that is licensed for aerial application.

Velpar has been tried with ground application using a Bracke mounted sprayer applying the herbicide as a stream along the sides of the scalps and broadcast from a separate carrier. Results were disappointing on all areas, and they may have to be sprayed again. However, having seen the success that Canadian Pacific Forest Products has had at Shebandowan Lake, it is suspected that something was not right in the API jobs. Velpar appears to be less effective than Vision on mountain maple (Acer spicatum Lam.) and beaked hazel (Corylus cornuta Marsh.), both of which are present on most of the sites requiring spray. It is therefore not seen as readily replacing Vision, even as a site preparation tool on API operations.

Planting

During the negotiations of the Spruce River Forest FMA, the company was adamant that large container stock was essential to get successful plantations on the sites it would be dealing with. Large is relative of course, and what was meant was seedlings approximately 15 cm tall with 500 mg mass, good active roots and a balanced seedling. The company had experience with private growers in the Thunder Bay area who had grown such stock for its freehold. Dr. John Scarrett of the Canadian Forestry Service had been giving advice and he too was certain that such stock would grow consistently. He had been doing so at greenhouses at the Great Lakes Forestry Centre.

Company foresters and executives had also had tours with Mr. George Marek of his Tyrol Lake plantations, and were influenced by his insistence that quality trees and care in planting were

essential ingredients for success. Mr. Marek was adamant that if tree seedlings do not meet your quality standards don't accept them. He was believed and is still believed, and company foresters act accordingly. They would rather not plant an area than plant it with trees they don't believe are adequate for the site.

During recent years, excellent bare root stock has been grown at the Thunder Bay Nursery of the MNR. Unfortunately, adequate cold storage facilities have not been available to store all of the stock; consequently, some stock has suffered overwintering damage in the field. API luckily received some of the undamaged stock, and snow cached it in 1987 and 1988. One million bare root stock was applied for in 1989, but unfortunately they were not allocated because of caps on seedling numbers. The company is now committed up to the level of the cap for the Spruce River Forest FMA through contracts for container stock with private growers. This arrangement is still preferred to depending on the MNR for bare root stock because of the direct control it gives over tree availability up to the number paid for by the MNR. The company is now free to grow the grades of stock it believes are required for its sites and is accountable for the consequences of its decisions.

Lakehead Woodlands' current preferences in summary:

1. Large bare root 1 1/2 + 1 1/2 or G+2 black spruce that was fall lifted and cold stored all winter or moved to snow cache in mid-winter for heavy competition sites. Black spruce grown in 408 paper pots or equivalent containers from February to May (current crop), then grown briefly outside and short day treated and overwintered appear to be an acceptable substitute. This would be planted on the roughly one third of the plant area that has severe grass competition;

2. Black spruce grown in 408 paper pots or equivalent containers in a greenhouse from April to the end of July and naturally hardened off outside or short day treated inside and overwintered outside (single crop). This would be planted on medium competition sites; and

3. Stock as in (2), but grown May to September and short day treated or extended greenhouse treated to November and overwintered outside. This would be planted on low competition sites.

Other growing regimes that give equivalent seedling grades could be acceptable.

Only those seedlings that meet individual contract specifications are guaranteed to be paid for.

Each fall the stock is allocated regardless of growing regime to the planting locations that the grades best fit; i.e., the largest and/or healthiest looking to the most competitive sites, and the smallest and least healthy accepted to the least competitive sites. Where chemical site preparation has occurred, a lighter grade of stock could be used.

Planting is confined to May and June to get a head start on grass and other vegetative competition, and to take advantage of the current growing season and planter enthusiasm. Larger stock and/or stock with larger buds, blue-green colour, and strong root systems, are planted earlier when practical because it is felt they flush earlier. When flushing becomes evident at the nurseries, there is an effort to move stock with the most advanced flush no matter what the theory may have been. Of course these are preferences, and practice is often different as operations adjust to circumstances.

Tending

Tending is similar to chemical site preparation in that Vision is the preferred herbicide because the most severe competition comes from blue-joint grass (Calamagrostis canadensis (Michx.) Beauv.) and red raspberry (Rubus idaeus L.). Where this develops after planting or before planting, and there was no chemical site preparation, Vision is applied aerially in the second or third year after planting. By this time some mortality or loss of seedling growth has occurred if the planting stock was small or of low vigour. However, earlier application of Vision could cause seedling damage.

Ground application is not felt to be practical because the seedlings are often invisible and mechanical application could cause damage. Manual application would be extremely expensive.

2,4-D has been applied to some NSR areas where beaked hazel, trembling aspen (Populus tremuloides Michx.), white birch (Betula papryifera Marsh.), and speckled alder (Alnus incana (L.) Moench spp. and rugosa (DuRoi) Spreng.) have been the main competitors. Use of 2,4-D has not always been successful and repeat sprays have been necessary, especially for aspen.

Both fixed wing and rotor wing aircraft have been utilized. No clear bias has developed for either, and the tendency is to select on the basis of contractor bids. This is partly because there is a selection of air strips around the division's limits. There is no clear evidence one offers any advantages over the other. The division is, however, moving to the use of bird dog aircraft in 1989 to ensure continuing accuracy of application, more direct control over beginning and end of the spray period, and to reduce any potential that may exist to make mistakes.

Seeding

The choice of seeding technique tends to be a factor of location, soil texture and/or vegetative competition, the amount of slash and/or the amount of cone bearing slash.

Seeding under shelter cones (Cerkons) is confined to locations south of the Thunder Bay 46 burn of 1980 and the freehold blocks. In 1989 it is confined to the freehold because there is no payment for this treatment on the FMA. Generally, to date, this method has only been used when there has been a shortage of seedlings, or where an area can only be accessed by a winter road. In 1989, some black spruce is being seeded with this technique on the freehold as a trial. The locations chosen are suitable for spruce, but have low probability of grass and raspberry developing.

Bracke seeding of jack pine is a common technique where full tree logging has occurred in jack pine and there is no natural seed source. Reasonable success has been achieved with this technique, but it tends to be expensive relative to Bracke site preparation without seeding. That is because contracts stipulate a maximum travel speed for the Bracke and contracts are supervised to ensure that speed is not exceeded and that the seeds are falling on the Bracke scalps. On the freehold it is common practice to follow Bracke seeding with aerial seeding the following winter if stocking surveys show marginal success.

Broadcast seeding of jack pine after tractor dragging still occurs, but tends to be done where there is slash accumulation and/or where there are cones on the site. Close supervisory attention to quality of site preparation, seed distribution, and site selection are essential to get consistent success for any seeding project.

CONCLUSIONS

Silviculture in 1989 is a different game from that of 1980-85 when FMA's were perceived by some as the answer to the question "who pays"; and the answer was, "the land owner, primarily MNR, with input from the licensee if he wishes to practise a more expensive level than the MNR has agreed to pay."

In the case of freehold, it was the land owner entirely, until 1985, when direct delivery partial financing from the Canadian Forestry Service, via the Canada/Ontario Forestry Agreement, became available. During those optimistic, if unrealistic days, silviculture was primarily site driven with some strong limitations on species to be managed for. Those days appear to be gone.

Today, silviculture is a weak competitor for public dollars, vying against health and other social service demands; and for

private dollars, being pitted against pollution abatement, changing technology, and alternative investments.

Silviculture decisions are based on using the available money to do the most of those prescriptions that will most nearly fill the company's wood requirements approximately to the year 2040 and thereafter. Site-specific silviculture is still the result, but treatments tend to be less intensive and possibly more innovative and challenging.

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MANAGEMENT UNIT STRATEGY FOR THE NORTHERN REGION

Bill Thornton

Ministry of Natural Resources
Timmins District

ABSTRACT

The Timmins Forest, the Forest Management Agreement with the Quebec and Ontario Paper Company, is examined as a sample management unit within the Ministry of Natural Resources' Northern Region, for the purpose of rationalizing silvicultural activities. This rationalization is difficult because the long term (rotation age) wood supply for most units has not been reliably quantified. Computer models, such as FORMAN and NORMAN, are being developed to better simulate wood supply. Meanwhile, silvicultural activities are directed by forest ecosystem classification surveys, prime land surveys, silvicultural guidelines for forest working groups and economic analysis, to varying degrees. Specific factors influencing silvicultural regimes on Timmins Forest are discussed. A geographic information system is needed to bring many of these tools together for the forest manager.

INTRODUCTION

As you can see from the agenda, I've been asked to speak on a management unit strategy for the Northern Region of the Ministry of Natural Resources (MNR). But before I begin, there's a couple of points I'd like to make.

First of all, I don't pretend to be a spokesman for the entire Northern Region. The Northern Region is about the size of New Brunswick, stretching from James Bay in the north, to the fringes of the Great Lakes - St. Lawrence Forest Region in the south. It's comprised of eight administrative districts and, as you can imagine, the silvicultural activities in the region are as varied as the sites and the people involved in managing them.

My experience has been in Timmins District, located in the middle of the Region, where I'm presently the Designated Crown Representative on the Timmins Forest. This management unit is a Forest Management Agreement area with the Quebec and Ontario Paper Company.

Secondly, I believe I'm one of the only speakers at this workshop who is actually working as a Designated Crown Representative or a Unit Forester. That's a little bit intimidating because it's generally up to guys like me and my industry counterparts to implement some of the tools and ideas that have been discussed here during the last two days.

This being the case, I'm not going to fool you into believing that everything we've talked about has been translated into action at the field level, because it hasn't. However, that's not to say that foresters like myself are unaware of these tools. They are being used to varying degrees, but generally haven't been developed to the point where they've become an integral part of our timber management planning process.

THE PROBLEM

When I was preparing this talk, I spoke briefly with Al Willcocks to get a better feel for what he meant by, "Applying the Principles," for the final section of the workshop. He phrased the problem like this:

> "Imagine that tomorrow you were suddenly to undergo a silvicultural audit. How would you justify or rationalize your present silvicultural activities?"

Well, that's a very simple, reasonable question for an auditor to ask, but it's also a hard one to answer to the satisfaction of an auditor. It's hard because we have difficulty in providing a quantifiable answer.

In the past, our silvicultural strategy was based largely on "chasing clearcuts." Once it was cut, we set about regenerating it, and at the time that was a major operational challenge. It

meant establishing and operating a large scale renewal and maintenance program where very little had existed before.

Nurseries sprung up and were challenged to grow better and better planting stock; site preparation equipment was tested and refined; major tree delivery and planting operations had to be coordinated; and better tending techniques were developed. With these preoccupations, there was no time to rationalize silviculture itself. The public considered it to be as fundamental as motherhood, and money was made available to support it.

However, times have changed. We've met our operational challenges, but now we live in a world of fiscal constraints, intense public scrutiny, and a greater need to rationalize our decision making.

The role of the forest manager is changing and the auditor won't accept an answer of, "Trust me, I'm a forester and I know what's best for the forest." Unfortunately, however, that's still often the best answer we can give at the field level.

BIG PICTURE/LITTLE PICTURE

Over the past twenty years, there's been a shift in forestry focus, from harvesting to silviculture. Silviculture came into vogue to such an extent that in some cases we thought it was the only game in town.

This narrow focus can become dangerous to the extent that we begin to believe that silviculture is the big picture. It's not. Silviculture is really a little picture (albeit a very important one) in the whole scheme of timber management. The big picture, as far as I'm concerned, is wood supply.

The question of long term wood supply from a management unit is even more fundamental than the question of rationalising silvicultural activities on the unit. How can there be a rational silvicultural strategy without first understanding the long term wood supply requirements from the unit? By "long term" I mean something in the order of rotation age, not simply 20 years.

As a field forester, I see wood supply as our Achilles heel. It's this big picture that makes the little picture so hard to explain. Once we are more able to quantify long term wood supply in terms of how much wood, for what product, at what time in the future, then our silviculture strategy will become much easier to rationalize.

So before I say anything on site-specific silviculture in the Northern Region, I'd first like to say a few words about understanding the big picture of wood supply.

UNDERSTANDING THE BIG PICTURE

I think it's fair to say that the long term wood supply picture from management units in the Northern Region is foggy: it's certainly not clear, but neither is it totally blank. This is probably true of most management units in the province.

However, tools are being developed to better understand wood supply. The Ontario Wood Supply and Forest Productivity (OWOSFOP) model has been with us for many years, but computer models such as Forest Management (FORMAN) are now giving us a better opportunity to simulate our forest management activities. The FORMAN model is currently being modified for the Northern Region and the new version, called NORMAN, should be available to foresters soon.

Ideally, these, and perhaps other computer models, will enable forest managers to identify probable periods of wood shortages with sufficient lead time to take corrective silvicultural action.

One big piece of the puzzle that needs more work is yield. We need better local information on not only the expected yield from managed stands, but from natural stands as well.

We must also recognize that these wood supply models need to be applied at the management unit level where the wood supply constraints of individual timber licensees can be accounted for. These constraints are often unaccounted for at a regional or provincial wood supply level.

I think it's inevitable that simulation models such as FORMAN or NORMAN become a standard requirement of our timber management planning process. However, it's currently a tool that hasn't been applied extensively, and as a result, our silvicultural rationale is less clear.

There are those who will say these simulation models are useless in the long term because of the future uncertainty in wood demand, product/price mix, technology, etc. But these uncertainties will always exist. More importantly, there's no doubt in my mind that an auditor will more readily accept actions based on reasonable assumptions of the future, rather than an explanation of, "Trust me, I'm a forester and I know what's best for the forest."

LITTLE PICTURE - SILVICULTURAL REGIMES

One area I feel we're very strong in is the operational aspect of delivering a silviculture program. In that sense, our past obsession with chasing clearcuts has really paid off. We can kick the stumps and feel the dirt and decide how to site prepare, plant and tend an area; and then do it, and do it well.

But when money gets tight, we may have difficulty in deciding whether it's better to spend $1,000 on regenerating one hectare versus $500 on each of two other hectares. Here's where considerations of economics and prime site management enter the picture.

Once again, these tools are available, but they are not being extensively applied in any quantitative manner at the management unit level. Part of the problem is the lack of information on expected volume yields from our activities. There's also uncertainty with respect to future product prices and appropriate discount factors.

But there's also the reality that if money is not a constraint, then this decision is irrelevant and we'll spend $1,000 on each of the three hectares to minimize our risk of failure.

What's often missing is a strong incentive for things like prime site management and low cost regeneration.

Other tools that are available to direct our silvicultural activities are the Forest Ecosystem Classification (FEC) surveys and the recently revised silvicultural guidelines for various forest working groups. These tools are being applied in the Northern Region.

TIMMINS FOREST - MANAGEMENT UNIT STRATEGY

The Big Picture

In keeping with my big picture/little picture scenario, I'd like to give you a general idea of the big picture for the Timmins Forest, Forest Management Agreement.

The licensee, the Ontario Division of Quebec and Ontario Paper Company, is a pulp and paper producer with a pulp mill located in southern Ontario (Thorold). About half of their fibre demand is supplied by recycled paper and the other half comes from wood on various private and Crown lands in Ontario.

Their principle species requirement from the Timmins Forest is black spruce (Picea mariana (Mill.) B.S.P.), but they also harvest jack pine (Pinus banksiana Lamb.) and exchange it for black spruce chips. Hardwoods are surplus to their needs, and are to be utilized by third parties.

In terms of long term wood supply from the unit, and possible wood shortages, there's very little to go on. The Quebec and Ontario Paper Company recognizes the need to maintain a continuous supply of black spruce fibre from the unit and has an ambitious silvicultural program to regenerate what it cuts, but the long term impact of its management practices, in terms of wood supply, has not been reliably quantified.

Timmins Forest - Description

Like most of northern Ontario's boreal forest, the Timmins Forest has a mature and overmature conifer component. Spruce is the largest conifer working group, followed by jack pine and balsam

fir (Abies balsamea (L.) Mill.). However, spruce budworm infestations have killed virtually all the balsam fir on the unit.

Timmins Forest is south of the clay belt, and is comprised of a mixture of upland and lowland sites. The variable terrain results in relatively small stands and the need for site-specific silviculture regimes.

The Little Picture - Silviculture Regimes

I won't bore you with tables of silvicultural regimes for each working group in Timmins Forest. They're pretty standard for the most part. The important point to note is that as site productivity improves, our silvicultural regimes become more intense. Instead I'd like to discuss three factors which are having more specific influences on our silvicultural regimes on the Timmins Forest.

The Spruce Budworm

Perhaps the most dominant factor in influencing recent silvicultural activity on the Timmins Forest has been the spruce budworm (Choristoneura fumiferana). This infestation has given rise to the development of two important tools.

The first is our prescribed burning program. When the budworm left large areas of dead balsam fir behind which could not be salvaged, the Company was faced with a dilemma. Not only did this dead, dry wood present a fire hazard to surrounding healthy timber, but it also effectively took large areas of their land base "out of production."

The result was greater interest in prescribed burning. Now its original attraction as a fire prevention tool has been replaced by its advantages as a silvicultural tool, to the point where it has become a standard part of our silvicultural regime for this working group.

However not all areas affected by the spruce budworm were readily burnable, especially where white birch (Betula papyrifera Marsh.) formed a significant portion of the stand. Nevertheless,

these were the more productive, upland sites and the company did not want to see them regenerate to more balsam fir and birch. As a result, they adopted a very expensive silvicultural regime of tramping, windrowing, planting and tending these sites.

About the same time, the Northern Region initiated a prime land inventory program for areas outside the clay belt. The cost of these detailed soil surveys were shared equally between the MNR and the company, and provided useful information.

(a) First of all, soil polygons were mapped at a scale appropriate for our planning - the FRI scale of 1:15,840;

(b) Secondly, they provided a prime land classification as a measure of soil productivity. This enabled us to direct expensive silvicultural investments to what we could prove were more productive sites;

(c) Thirdly, they provided information on things like texture, drainage, moisture regime, soil depth and stoniness, which had important silvicultural applications;

(d) Fourthly, they included a terrain classification developed by the Forest Engineering Research Institute of Canada (FERIC) which provided operational information on ground strength, ground roughness and slope; and

(e) Finally, this information was also digitized for use on a Geographic Information System (GIS).

Spruce vs. Pine

As I mentioned earlier, Quebec and Ontario Paper Company has a strong preference for black spruce over jack pine. This is reflected in their silvicultural regimes where they will often plant spruce on former jack pine sites which are capable of growing spruce.

Once again, our detailed soil survey information has been useful in identifying these sites. While it's clear these sites will not grow spruce at the same rate they would have grown jack pine, these plantations will usually outperform plantations on the true spruce sites, provided competition is controlled.

Natural Regeneration

Another area receiving greater attention is natural regeneration, particularly with constraints on planting stock and money. One problem we've had is identifying pockets of natural regeneration so that they are not needlessly included in artificial regeneration operations.

A useful tool in this regard has been spring infrared photography, which provides easy identification and stratification of conifer regeneration. This applies not only to recent cutovers, but also to Not Satisfactory Regenerated (NSR) lands - many of which we've discovered are satisfactorily regenerated.

Recently the Northern Region has purchased a Procom-2, which we use as a mapping projector for transparencies such as satellite imagery and infrared photography. The Procom-2 has a zoom lens that can enlarge the projection to any scale. This can be used with low level infrared photography to map areas of natural regeneration at a 1:15,840 scale, and to quantify levels of conifer stocking.

PUTTING IT ALL TOGETHER - GIS

We've talked a lot about rationalizing forest management decisions and applying various tools for site-specific silviculture. But everything seems rather fractured and intangible until we see it on a map or on the ground. In order to put this all together, we need a geographic information system.

Other provinces such as New Brunswick and British Columbia have been making operational use of GIS technology for several years. Recently, Timmins District has become part of a GIS pilot project, and several companies in the Northern Region, especially Abitibi-Price, are involved in GIS development work as well.

This should greatly enhance our ability to link the big and little pictures I've spoken of. The Northern Region is a strong supporter of GIS development.

CONCLUSION

I hope that gives you some idea of a management unit strategy in the Northern Region. Most of the tools for site-specific silviculture are out there, and we are trying to make use of them. The problem now is putting them all together.

We look forward to providing better answers for our next silviculture auditor!

MANAGEMENT UNIT STRATEGY FOR CANADIAN PACIFIC FOREST PRODUCTS LIMITED

Niels Carl

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ABSTRACT

The forest industry is concerned with wood cost, quality and quantity. However, it must also consider consumer requirements and proper management of the resource when pursuing profits. The industry must set objectives and decentralize to the operating level. The mill is the profit centre; silviculture cannot be rationalized in isolation. The company's silviculture program needs to be rationalized using computer projections of growth and yield. Wood quality is being addressed through tree improvement.

INTRODUCTION

The introduction of Forest Management Agreements has resulted in a renewed cooperation between Government and Industry to manage the forest. The responsibility has finally been placed where it belongs - with the industry that harvests the forest. This paper will outline the strategy that Canadian Pacific Forest Products Limited, Thunder Bay Division, has developed to manage the forest area.

Company Objective and Strategy

The Company's objective is to produce forest products which can be marketed at a profit and on a sustained yield basis. Like any organization, the survival of the Company is paramount. Survival in the competitive forest industry depends upon a number of factors:

1) WOOD COST;
2) WOOD QUALITY; and
3) WOOD QUANTITY.

All of these variables must be recognized and managed to ensure the Company's success.

Management of the forest resource requires planning and action. The Resource Management Strategy which works best is borrowed from the Environmentalist vernacular:

"THINK GLOBALLY, ACT LOCALLY."

"Think Globally"

Corporate planning must produce clear policy, objectives and strategy known by everyone.

Planning must be a group effort with differing intensity and duration, depending on the group and its responsibility. Woodlands planning must reflect the realities of a resource-based industry as illustrated in Figure 1, "The Foundation of the Forest Industry." The forest industry must meet the requirements of the market place; i.e. the consumers. The industry must also recognize the resources it is based upon, both natural and human. The forest industry must understand and apply fundamentals of forest management. It must also recognize the importance of human resources.

Ultimately society, the owner and the consumer of the resource, will decide the fate of the industry. Therefore, the industry must consider the cost benefit of resource management to people when assessing the bottom line. The cost benefit of resource management can be expressed as follows:

Cost/Benefit of Resource Management to People	=	Cost/Benefit to Natural Resource	+	Cost/Benefit to the Consumer	+	Cost/Benefit to Operations (Harvesting, Milling, Silviculture).

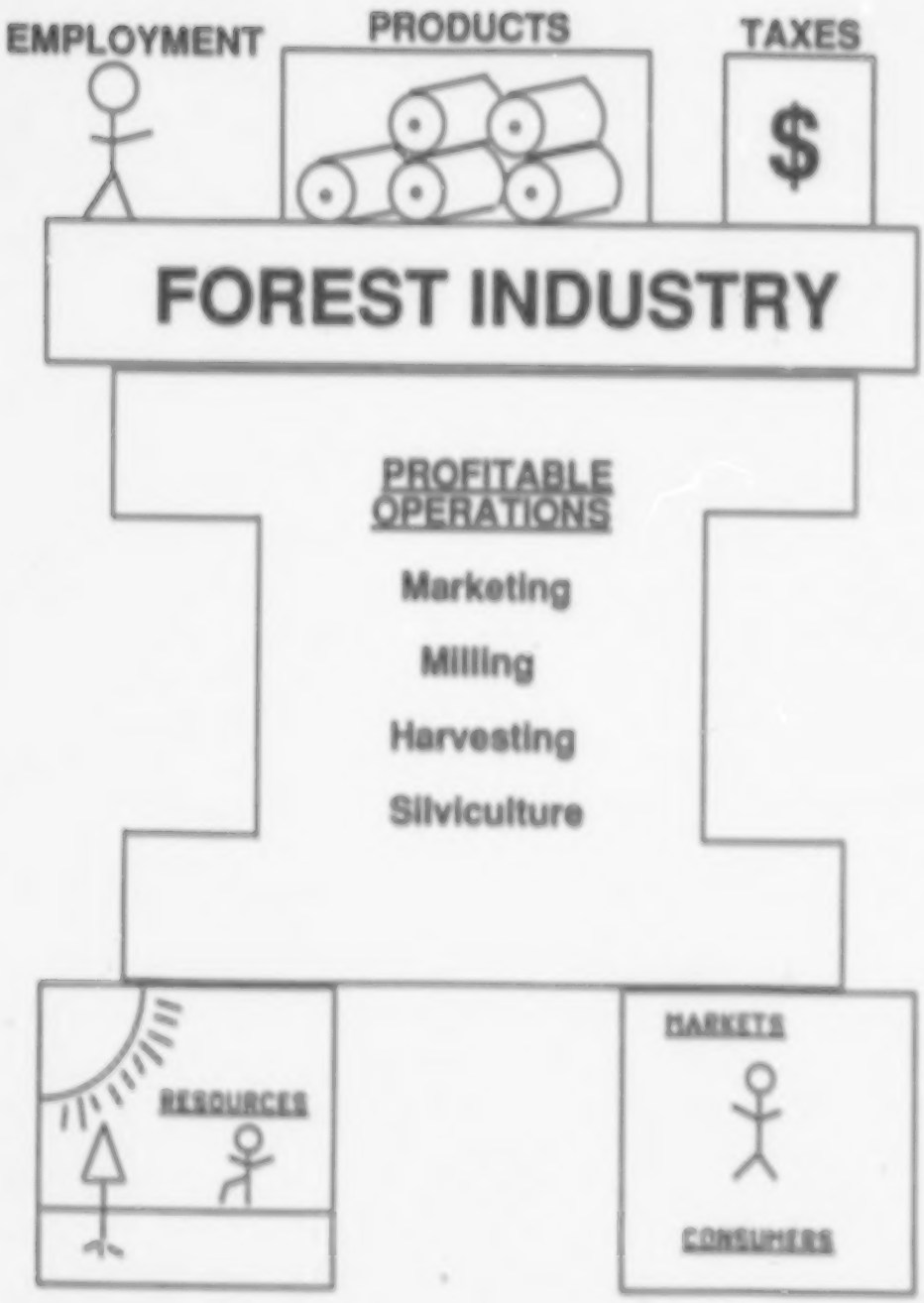

Figure 1. Forest industry operations depend on market place demands and the availability of natural and human resources.

"Act Locally"

Once policy, objectives and strategies are developed, communicated and accepted, management must MANAGE, not administer. Management must take responsibility and:

Listen

Communicate

Organize (people and thinking)

Decentralize

Delegate accountability to local people while providing support and overall leadership. Resource management requires that capable people with local knowledge and experience and a clear understanding of corporate objectives be given the responsibility to conduct operations. If an industrial organization is to be successful, it must be organized to operate and produce at a profit, not to administer. That is the fundamental difference between government and industry organizations (Figure 2).

Resource Management and Economics

If forest managers use economic analysis of silviculture treatments, it should be to optimize cost/benefit; i.e. choose the most cost effective treatment. Silviculture cost is a small component of total product cost (Figure 3), yet it is the basis for the industry. It does not make sense to reduce costs in silviculture to the point where the industry is jeopardized. This does not preclude using cheaper methods where results are acceptable.

When using economic analysis, it must recognize the mill as the true profit centre (the province is not a profit centre; the forest industry is not a Crown corporation - yet). Harvesting and silviculture are cost centres.

The forest industry is in business to make a profit, not to save money on silviculture.

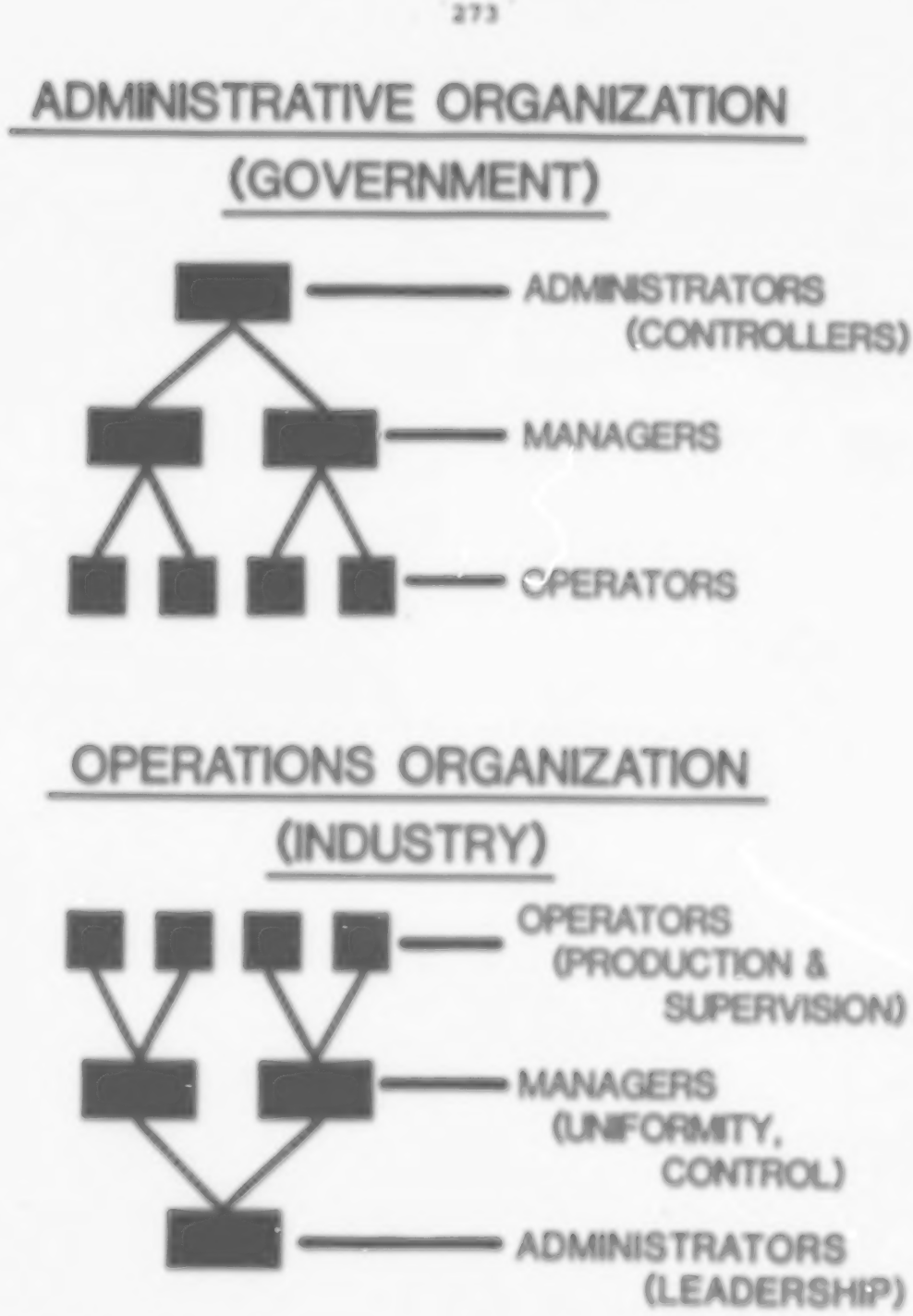

Figure 2. The administrative set-up of the government vs. the operations-based organization of the forest industry.

SILVICULTURE AS A % OF PRODUCT COST

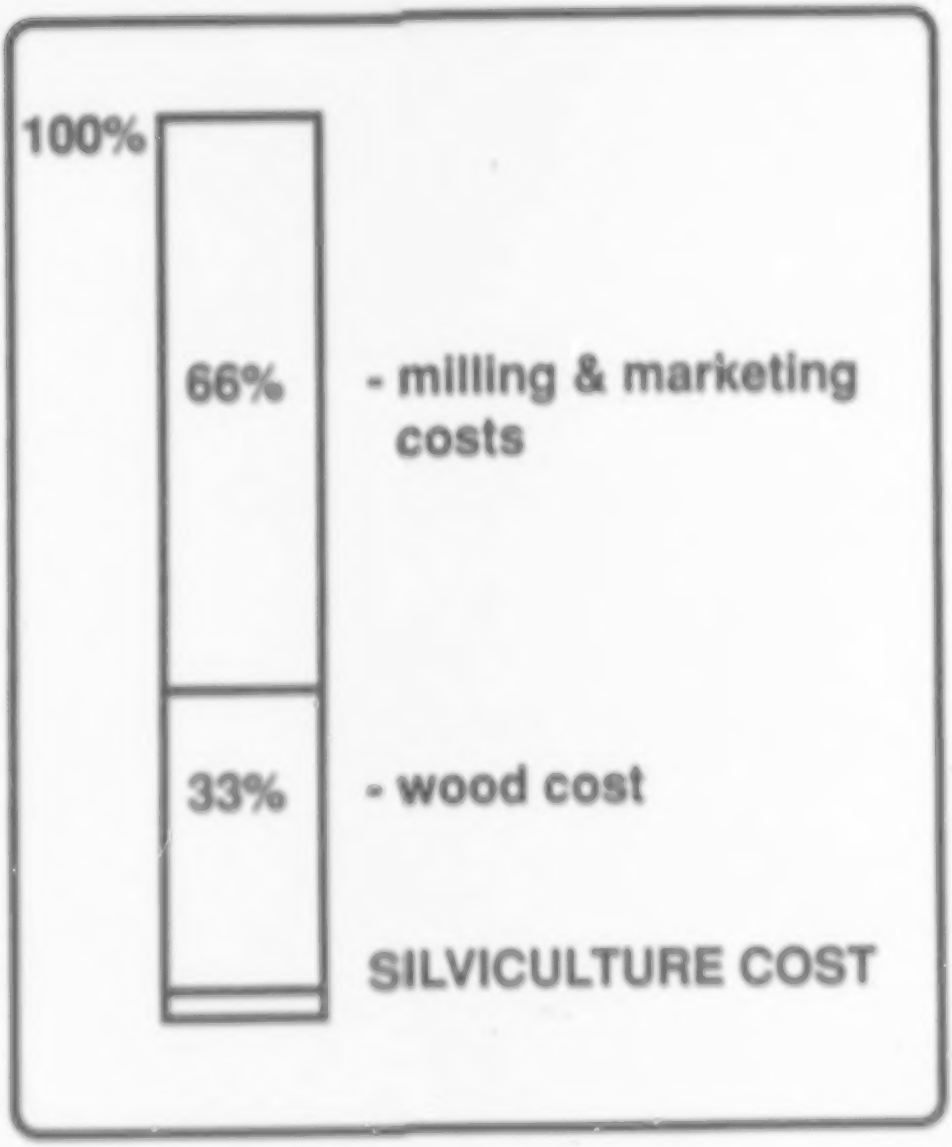

Figure 3. Silviculture cost is a small component of total product cost.

The Silviculture Program

The company's program is distributed as follows:

Regeneration Method

Natural	20%	60% extensive
Seeding	60%	40% intensive
Planting	40%	

The planting level is currently too low, to the point where the company is using extensive treatments on sites which should be planted. In an attempt to convince the government to supply more trees, the company is using the FORMAN program to test the volume of wood produced by different planting, seeding and thinning levels. The licence has been divided into two zones, intensive and extensive. The company is planning to classify stands by productivity using features which can be photo-interpreted. Therefore, species could be used in combination with soils, and interpretations made from landforms from the Ontario Land Inventory and NOGETS maps. Operating (treatment) units could be developed using a combination of the species and site, and then be plotted using GIS. Prescriptions could then be by operating units, as illustrated in Figure 4.

The company is using Plonski's yield curves for the natural stands, but would prefer that Regional curves be developed. The managed stands are based on curves developed by the Technology Development Unit, blended with natural curves to reflect the mixture of natural and artificial regeneration in our plantations, which results in variable stocking.

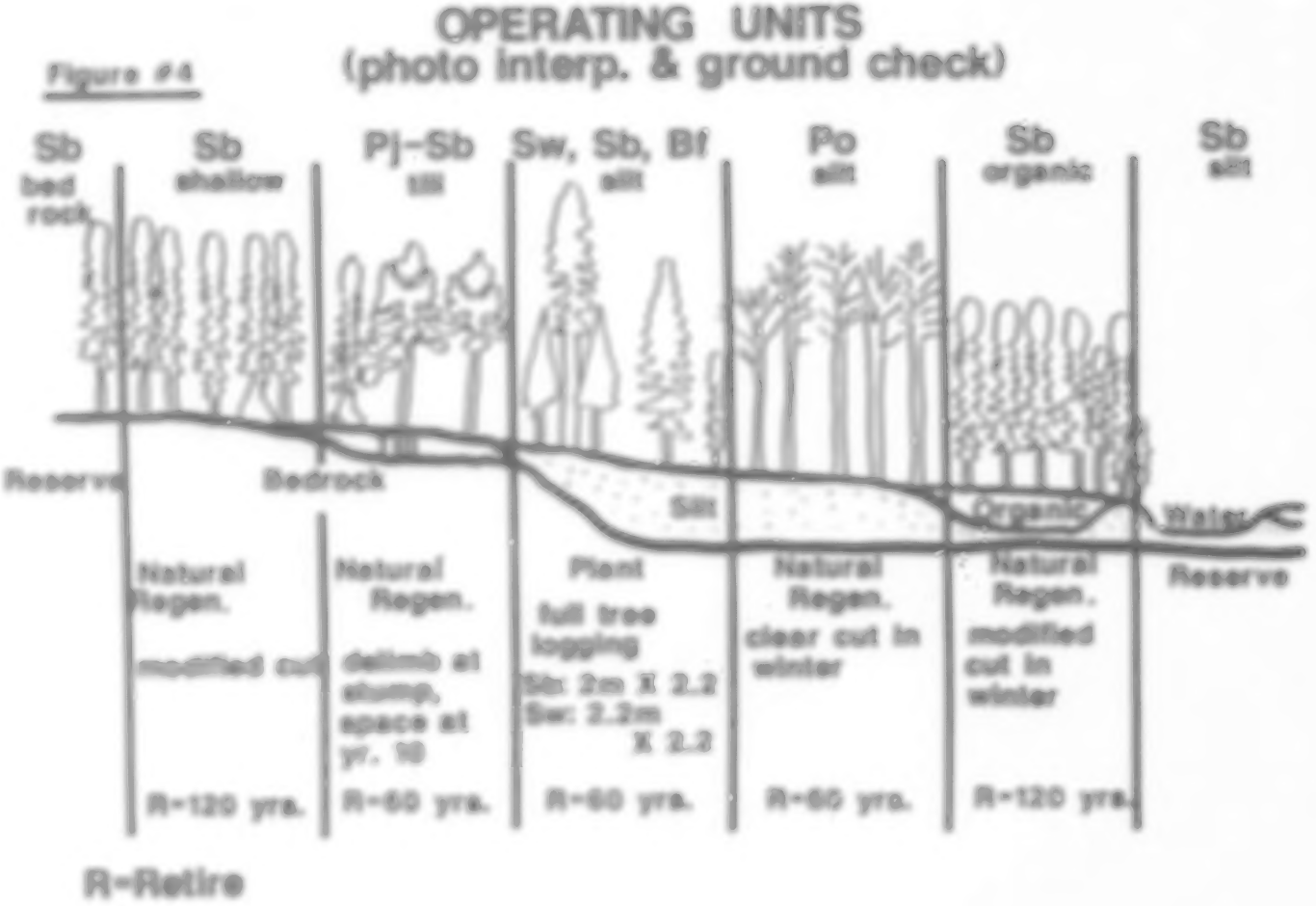

Figure 4. Photo interpretation of features, e.g., species, soil, and landforms are used to classify stands.

WOOD QUALITY

The company is concerned with the quality of wood that will be available. Wood quality varies with the product as summarized in Tables 1 and 2. The company produces a variety of products, so that all species can be used. In addition, the company is working to maintain or improve wood fibre characteristics through silviculture and tree improvement. For example, for jack pine (Pinus banksiana Lamb.) the objective is to produce wood which can be used in paper and lumber production, at reasonable processing costs, to produce competitive products. The fibre characteristics preferred are: long fibres, moderate cell wall thickness, moderate specific gravity, uniform fibres, low resins, minimum knots, and minimum compression wood. The company is a cooperator in the Ontario Tree Improvement Council.

The company is also considering the influence of silvicultural treatments and rotation on jack pine wood properties as outlined by K.C. Yang (Table 3). Careful consideration must be given to the effects of intensive management on wood characteristics.

CONCLUSION

The forest industry must have sufficient good quality wood at reasonable cost to ensure its survival. The industry must address consumer needs and manage the resources for the long term. Woodland organizations must have long term objectives that are translated to local targets, and which are the responsibility of local people. The company's silviculture program has grown dramatically since the first F.M.A. in 1960. The program now needs to be fine tuned through computer projections of growth and yield. The company has also embarked on a tree improvement program to improve fibre in the long term.

Table 1. Pulp and paper fibre requirements.

NEWSPRINT KRAFT PAPER LINERBOARD	Long Fibre Good Strength (cell wall/length ratio) low extractives	Spruce, Pine
FINE PAPER	Long & Short Fibres low extractives	Spruce, Pine, Poplar
TISSUE PAPER	Short Fibres low extractives	Poplar, Spruce

K.C. Yang
G.A. Smook
N. Carl

Table 2. Lumber fibre requirements.

Dimensional Lumber	- minimize juvenile wood, taper, knots (mature Jack Pine, White Spruce, Red Pine)
Pressure Treated Lumber	Wide sapwood, low extractives large cell wall openings (mature Jack Pine, Red Pine)

K.C. Yang
G.A. Smook
N. Carl

Table 3. Influence of silvicultural treatments and rotation on jack pine wood properties in young trees.

WOOD PROPERTIES	SPACING	THINNING	FERTILIZATION	SHORT ROTATION
Specific gravity	—	±	—	—
Fibre length	—	—	—	—
Latewood %	—	—	—	—
Juvenile Wood	+	+	+	+
Growth ring	+	+	+	+
Sapwood/Heartwood %	+	?	+	+

K.C. Yang

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Smook, G.A. 1982. Handbook for Pulp & Paper Technologists, I.S.B.N. 0-919893-00-7.

Yang, K.C. 1986. Wood Properties, Wood Qualities, Silvicultural Treatments and Forest Management.

WORKSHOP SUMMARY

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This workshop entitled "Tools for Site Specific Silviculture in Northwestern Ontario" began with a discussion on site productivity and forest ecosystem classification, the basic building blocks for all silviculture. The workshop concluded with how some agencies applied silvicultural principles to their forests. In between speakers outlined the many types of silviculture tools that could be applied to achieve silvicultural objectives.

Most of you were enticed to come to this workshop to learn about the new tools available. Others were interested in organization/stratification of forestry sites using forest ecosystem classification. Some of you were hoping for some simple solutions to complex problems.

For myself, the workshop changed my thinking about silviculture. Until now I had always concentrated on how to apply silviculture (ie. trees per/ha planted, type and rate of chemical applied, etc.). Now I ask the question, "why do silviculture?" Some possible answers to the 'why' question could be as follows:

- our responsibility to the public (motherhood);
- to continue future production from a site;
- fulfil targets.

Presently, foresters base most of their silvicultural choice on qualitative reasons, rather than quantitative. As Dr. Gordon Baskerville[1] found, the forest units he surveys in Ontario did not

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[1] G.L. Baskerville. 1986. An Audit of Management of the Crown Forests of Ontario. Ont. Min. Nat. Resour. 97 pp.

have plans that match silvicultural efforts to the needs (or management objectives) of the forest owner. Some foresters, as inferred in the above, often treat silviculture as the management objectives. Did our speakers in the section, "site specific silviculture - applying the principles,' illustrate this point in their presentations? Did they match their silvicultural effort to their forest level needs?

A second important question asked by many is, "why apply certain silvicultural treatments?" Possible contemporary answers to this include:

- to regenerate a stand to its original forest;
- tradition;
- works elsewhere; and/or
- the mill needs conifer, therefore we must grow conifer.

As in all workshops, I'd like to challenge you to consider other silvicultural approaches (ie. forget tradition for awhile) to implement your forest management objectives. Many different ideas were presented at this meeting but most were not new technologies; just not tried or used in NOrthwestern Ontario. Don't fall into Tim McCarthy's "Double Not Syndrome", where just because the idea or person is from outside your province, District or unit, it's not good. If the shoe fits, try it on - but be careful, make sure it fits well. Remember the Edse.

In summary, silviculture is a means to achieve forest management objectives or needs of the forest owner. Before we apply silviculture, determine these needs and match these with the appropriate amount of silvicultural treatments. With this in mind, we should have named this workshop to "The Use of New/Old Silvicultural Tools to Achieve Forest Management Objectives in Northwestern Ontario."